Constructing Knowledge-based Industries in the Globalization Era:
Social Learning, the Political Process and Commitment Strategies

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Constructing Knowledge-based Industries in the Globalization Era:
Social Learning, the Political Process and Commitment Strategies

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DEDICATION

To My Family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACOA	Atlantic Canada Opportunities Agency
AAFC	Agriculture and Agri-Food Canada
AIMS	Australian Institute for Marine Science
ASX	Australian Stock Exchange
BCG	Biotechnology Consultative Group
BDC	Business Development Bank of Canada
BioNB	Bio New Brunswick
BMCC	Biotechnology Ministerial Coordinating Committee
BRI	Biotechnology Research Institute
BUDS	Biotechnology Use and Development Survey - Canada
CAFTA	Canadian Free Trade Agreement
CAN	College of the North Atlantic
CBAC	Canadian Biotechnology Advisory Committee
CBS	Canadian Biotechnology Strategy
CIPO	Canada Intellectual Property Office
COMET	Commercializing Emerging Technologies
CQDM	Québec Consortium for Drug Discovery
CRO	Clinical Research Organization
CSL	Commonwealth Serum Laboratory
DBF	Dedicated Biotechnology Firm
EACSR	External Advisory Committee on Smart Regulation
GDP	Gross Domestic Product
GMiA	Generic Medicines Industry Association
HRSDC	Human Resources and Skill Development Canada
IBRD	Department of Innovation, Business and Rural Development
IIO	Innovation Institute of Ontario
INB	Invest New Brunswick
IP	Intellectual Property
IPO	Initial Public Offering
IPR	Intellectual Property Rights
IR&D	Industry Research and Development
IRAP	Industrial Research Assistance Program
LSO	Life Sciences Ontario
MaRS	Medical and Related Sciences
MDEIE	Ministry of Economic Development, Innovation and Exports
MEDEI	Ministry of Economic Development, Employment and Infrastructure

MEIE	Ministry of Economy, Innovation and Exports
MNC	Multinational Corporation
MOSST	Ministry of State for Science and Technology
MoST	Ministry of Science and Technology
MRI	Ministry of Research and Innovation
NAFTA	North America Free Trade Agreement
NAS	National Academy of Sciences
NATI	Newfoundland and Labrador Association of Technology Industries
NB	New Brunswick
NBAC	National Biotechnology Advisory Committee
NCATS	National Center for Advancing Translational Science
NCE	New Chemical Entity
NHMRC	National Health and Medical Research Council's
NIH	National Institutes of Health
NIS	National System of Innovation
NL	Newfoundland
NLAN	Newfoundland and Labrador Angel Network
NLCHI	Newfoundland Center for Health Information (NLCHI)
NRC	National Research Council
NS	Nova Scotia
NSERC	Natural Sciences and Engineering Research Council of Canada
NSF	National Science Foundation
NVCF	Northleaf Venture Catalyst Fund LG
NYSE	New York Stock Exchange
OBEST	Ontario Bioscience Economic Strategy Team
OBIO	Ontario Biotechnology Industry Organization
OCGC	Ontario Capital Growth Corporation
OECD	Organization for Economic Cooperation and Development
OETF	Ontario Emerging Technologies Fund
ON	Ontario
ORFAB	Ontario Research Fund Advisory Board
OSTP	Office of Science and Technology Policy
OTA	Office of Technology Assessment
OVCF	Ontario Venture Capital Fund LP
PBS	Pharmaceutical Benefits Scheme
PEI	Prince Edward Island
PFC	Project-focused companies
PIC	Pharmaceuticals Industry Council
PLQ	Quebec Liberal Party
PMPRB	Patented Medicine Prices Review Board

PQ	Parti Québécois
PRO	Public Research Organization
QB	Quebec
R&D	Research and Development
RDC	Research and Development Corporation
rDNA	Recombinant DNA
RFP	Request for Proposal
RIS	Regional Systems of Innovation
ROI	Return on Investment
S&T	Science and Technology
SBI	Science-based Industries
SEUS-CP	Southeastern United States - Canadian Province
SME	Small and Medium-sized Enterprises
SR&ED	Scientific Research and Experimental Development
SSI	Sectoral System of Innovation
STEM	Science, Technology, Engineering and Math
TBI	Toronto Biotechnology Initiative
TPC	Technology Partnerships Canada
TRIPS	Trade-related Aspects of Intellectual Property Rights (TRIPS)
USPTO	U.S. Patent and Trade Office
VC	Venture Capital
VCR	Venture Capital Registration
VOC	Varieties of Capitalism
WIPSI	Workplace Innovation and Productivity Skills Incentive
WTO	World Trade Organization

SUMMARY

Over the last few decades countries have been promoting knowledge-based industries, especially those requiring a significant scientific base like bioscience, as engines of economic growth. Developed and, increasingly, developing economies see knowledge-based industries as providers of skilled jobs, higher wages and technological innovation. Not only do industries heavily reliant on finance, research and development (R&D) and skilled labor innovate, but more traditional industries like agriculture use new technologies to upgrade products and processes. This transformation of the economic base, the argument continues, creates wealth and sustainable economic growth.

This research address two puzzles: Why do similar regions within countries pursue different commitment strategies towards growing their bioscience industries? Why do some change in response to a global financial shock and others do not?

I argue that the presence and strength of a knowledge-oriented strategy team (KOST) helps to explain different levels of and changes in bioscience commitment strategies. Different degrees of social learning – disruptive or incremental, and type of iterative bargaining – coordinated or fragmented distinguish a strong KOST from a weak or non-existent one. This explanation as well as province's size, natural resources, national institutions and path dependence more fully explain variation in commitment strategies.

The research design includes comparisons at the national and sub-national level. The study compares three similar industrialized and federalist countries – Canada, Australia and the United States – emphasizing Canada. The study applies a most similar systems approach comparing the two large, industrialized provinces of Quebec and Ontario. Separately it compares the small, rural provinces of Atlantic Canada including New Brunswick, Newfoundland, Nova Scotia and Prince Edward Island. Together these cases form a national composite of regional differences.

The most significant finding of this research is that those Canadian provinces that established a strong KOST *prior to* the 2008 global financial crisis "puzzled and powered through" to maintain high level commitments to their bioscience industries afterwards.

CHAPTER 1

COMMITMENT STRATEGIES AND SCIENCE-BASED INDUSTRIES

1.1 Introduction and Puzzles

Over the last few decades countries and regions within them have been promoting knowledge-based industries as engines of economic growth. Strategies have specifically addressed those industries requiring a significant scientific base such as bioscience.[1]Industrialized and increasingly developing economies see them as providers of skilled jobs, higher wages and technological innovation. Science-based industries rely heavily on finance, research and development (R&D), and skilled labor to innovate, while traditional industries such as agriculture also use new technologies to upgrade products and processes.[2] This transformation of the economic base creates wealth and strengthens global economic competitiveness.

However, global shocks including a technological discovery or a financial crisis often disrupt this process. In response, regions and countries develop different commitment strategies in support of these industries. This dissertation attempts to improve our understanding of and explanations for what happens immediately after a global shock. It

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[1]The OECD defines "knowledge-based economies" as "economies which are directly based on the production, distribution and use of knowledge and information…In the knowledge-based economy, innovation is driven by the interaction of producers and users in the exchange of both codified and tacit knowledge; this interactive model has replaced the traditional linear model of innovation" (OECD, 1996, p. 7). Powell provides a more balanced definition, capturing both the productive and destructive elements, "…production and services based on knowledge-intensive activities that contribute to an accelerated pace of technical and scientific advance, as well as rapid obsolescence…The key component of a knowledge economy is a greater reliance on intellectual capabilities than on physical inputs or natural resources" (Powell & Snellman, 2004, p. 5). Since I am primarily interested in how countries and regions choose strategies and change institutions in support of bioscience industry growth, I employ the Powell's definition.

[2]I rely on Noisi's definition of a "Science-based Industry" for this study. Here, firms and organizations with a relatively high ratio of R&D spending as a percentage of revenue is a key factor in determining whether or not the industry draws significantly from the development or use of scientific knowledge (Niosi, 2000, pp. 429-444).

examines bioscience within the industrialized and federalist country of Canada and its provinces as cases.[3]

Puzzle: Why do similar regions within countries pursue different commitment strategies towards growing their bioscience industries? Why do some change in response to a global financial shock and others do not?

Bioscience institutions help create opportunities for growth while managing risks associated with it. This is not surprising since theories of institutional change claim that individuals and organizations design institutions to capture opportunities that they could not on their own. Some organizations are constantly experimenting with new ways of coordinating economic activity to effectively facilitate the development of a bioscience industry since rapid technological change and uncertainty characterize the process leading to unusually high costs. But few theories explain how and why these formal and informal rules develop in the first place, how they change over time and why they vary across similar jurisdictions trying to tackle the same problem.

Regions within countries are arguably the source of innovation. They design different institutions with varying degrees of success in transforming their industrial base despite the fact that they face the same globalization pressures and operate within the same national context (D. Wolfe & Gertler, 1998).[4]Initial conditions such as the type and amount of natural resources, existing industrial structures, population and land size partly explain the different types of commitment strategies and ultimately industrial

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[3] I refer to Dahl's definition of federalism, "a system in which some matters are exclusively within the competence of certain local units – cantons, states, provinces – and are constitutionally beyond the scope of the authority of the national government; where certain other matters are constitutionally outside the scope of the authority of the smaller units" (Dahl, 1986, pp. 114-126).

[4]I examine provincial level strategies since authority for designing industrial policies is shifting to or at least shared with provinces or states within countries and across many types of organizations. In addition, provinces both implement and influence national bioscience institutions. This is not to say that cities are not important actors in the process. But provincial agencies can aggregate interests across cities in the form of a policy community or a knowledge-oriented strategy team (KOST).

transformations. Holding these variables constant we still observe significant variation in both formal and informal rules with implications for industrial change.

I draw upon the comparative political economy, historical institutionalism, institutional economics, economic geography and economic sociology literature to explain different commitment strategies associated with the bioscience industry. Below is a summary of the theory. Chapter two more fully elaborates the variables and causal mechanisms.

1.2 Theory in Brief

I examine the presence and strength of a *knowledge-oriented strategy team* (KOST) to explain varying levels of and changes in commitment toward a bioscience industry. States and regions typically generate formal strategies that inform that institutions are created, changed or decommissioned. But not all design formal strategies and even those who do often end up not implementing them. Some countries and regions follow the normal policy-making process by changing levels and types of investment in finance, skills and corporate governance without a major paradigm shift. Other countries change paradigms and overarching goals in partnership with society. All represent different levels of commitment towards capturing the benefits of the new technology while minimizing its risks. The presence and strength of a KOST helps to understand this variation.

1.2.1 Dependent Variable: Commitment Strategy

The dependent variable is "commitment strategy" including both the *change in* and *degree of* commitment. I conceive of commitments as institutions that have been created or changed as part of a larger strategy to develop a bioscience industry. Institutions can act as credible commitments necessary to facilitate low-cost transactions especially when they are specialized, difficult to reverse, and include incentives that are aligned with the skills and knowledge perceived to offer the highest payoff (Kreps, 1996; D. C. North, 1993). In other words, given the rising complexity of the science and nature of the industry it is too costly for bioscience organizations to act alone. Formal and informal rules that enable organizations to capture new opportunities at a lower transaction cost are necessary.

I define a high commitment strategy as one where institutional complementarity in areas of finance, skill development and corporate governance exists. Each area includes formal and informal rules designed to reach shared, overarching goals among them. This complementarity represents a more holistic and strategic approach in support of bioscience industry goals.

A mixed commitment strategy includes complementarity between two institutional areas like corporate governance and finance but not a third such as skill development. In this example industry and its firms may improve competencies by creating advisory or governing boards. The expectation is that boards will bring global networks of “angel” investors or venture capitalists who can contribute much needed financing and advice regarding corporate strategy. Without access to trained technicians, specialized researchers, or commercialization experts the strategy is in jeopardy of not reaching its goals. This approach is not holistic.

A lack of institutional complementarity among the three areas equates to a low commitment strategy. In this case the commitment may include R&D investments but not immigration policies, technical programs or new university degrees designed to attract or produce bioscience skills required to conduct R&D effectively.

To capture *change* in commitment strategies I first compare in each case the level of institutional complementarity before and after the 2008 global financial crisis and determine whether or not there was a change. Did any jurisdiction shift from lower R&D spending levels, few training programs and little collaboration experience between small biotech and large pharmaceutical firms to a fundamental paradigm change leading to higher levels of commitment? The direction of change toward higher or lower levels of institutional complementarity should become clear using this approach. This method also captures cases where there was no change before and after the crisis.

I examine the presence and strength of a KOST to explain levels of and changes in bioscience commitment strategies in institutional levels of settings, programs and overarching goals. Settings include measures like the amount of R&D spending. Programs involve systems to deliver resources such as a venture capital mechanism.

Overarching goals reflect how countries and provinces frame the industry's opportunities and costs within a vision for growth. Goals change when a paradigm shift occurs about where the opportunities lie and how to capture them. Shifts from basic research to technology commercialization or from individual firm R&D to collaboration projects via alliances with other organizations represent such changes. The section below illustrates the types of strategic choices that jurisdictions face and their relation to levels of commitment.

Increased competition, rapid innovation, scarce resources and the rising complexity of the science have combined to shape common understandings of the problem and its solution. Post-2008 countries and regions embraced strategic approaches to developing their bioscience industries. Elements included leveraging resources across and within public and private sector organizations, creating interdisciplinary means to skill development, and establishing overarching goals directly related to economic growth. But tactically they differ in the commitment strategies they create. This difference is partly due to how choices are framed.

The list below illustrates tensions inherent in these choices.

- Public versus private sector leadership
- Macro versus micro-level (top-down, big successes faster versus "bubbling up" from the bottom at slower pace)
- Horizontal versus specialized R&D and industry focus
- FDI-led versus local industry-led development (creating knowledge-spillovers)
- Basic research versus commercialization
- User versus producer of biotechnologies
- Finance (public versus private, local versus global)
- Skills (local versus global)
- Bioscience versus other knowledge-based industries like ICT and Aerospace as well as traditional industries like agriculture, fisheries, basic manufacturing

High commitment strategies include institutional complementarity at all levels of settings, programs and overarching goals within finance, skill development and corporate governance. For example, increasing and diversifying R&D financing within the context of new ways of thinking about the role of finance can be coupled with similar changes in developing the skills and corporate strategies required to achieve new industry goals.

The process of creating the commitment involves a strong KOST led by a specific government agency or industry association. Disruptive social learning occurs as participants frequently interact, sharing and reviewing technical reports, market trends, competitor analyses, new discoveries as well as monitoring and evaluating industry results, generating lessons learned from previous approaches and changing them as necessary. Decisions to change settings, tools and overarching goals result from regular discussions among diverse stakeholders and sometimes in response to a global shock or to a gradual understanding that future economic growth lies in knowledge-based industries.

The diversity of stakeholder involvement in the strategy team can ultimately cultivate more opportunities for solutions. While these deliberations are often conflict-laden they can lead to consensus around how to proceed. But clearing this high bar is difficult and rare.

Maintaining high levels of commitment to bioscience strategies is difficult and includes learning mechanisms that maximize the effectiveness of seemingly competing approaches. For example, jurisdictions like PEI and Quebec take nuanced approaches to solving the risk and return challenge. PEI balanced specialization with diversification rather than choosing between horizontal or specialized R&D. The province drew from its natural resources and committed to developing a bioactives niche broadly applicable to human and animal health.[5]

Rather than choosing between FDI-led or local industry-led growth, addressing weaknesses in *relationships* between multinational corporations (MNCs) and local firms can create sustained opportunities and improve the quality of FDI. Weaknesses include

[5] Often the decision is framed as market-led versus government or industry “picking winners.”

lack of local firm science or project management capabilities and scant information on local industry and incentives for MNCs to collaborate. Based on these measures and according to the data, Prince Edward Island and Quebec pursued high commitment strategies before and after the 2008 global financial crisis.

In mixed commitment strategies the nature of the political process involves a weak KOST or the absence of a KOST but multiple policy communities. A weak KOST engages in incremental social learning combined with a coordinated, iterative bargaining approach. It is incremental and coordinated when there is some search globally for lessons learned, but changes in particular policy settings and techniques occur mostly in response to previous policy experience. There is no change in overarching goals or in political paradigms. Typical strategy elements include framing the problem as states versus markets and letting individual firm strategy lead. Ontario pre-2008 and Nova Scotia post-2008 fits this description.

The other type of mixed commitment strategy involves the absence of a KOST. Separate policy communities engage in disruptive social learning within their own community, but compete among each other for resources. Elements of this type tend to reflect the tensions in the policy choices elaborated above. These include favoring commercialization over basic research, downstream over upstream R&D, investing in high-potential R&D rather than “R&D democracy” where financing is spread equally among firms and regions. Ontario, New Brunswick and Newfoundland post-2008 and Nova Scotia pre-2008 are representative cases (McKenna, 2011, p. 1).

In low commitment strategies neither a KOST nor a bioscience strategy exists. Minimal social learning occurs and is reflected primarily in changes in settings like levels of R&D funding to universities. The bargaining process is fragmented since few if any strategy communities coordinate their efforts. The benefits of growing a bioscience industry are either not understood or compete with industries that are perceived to be more promising like digital media, oil and gas. New Brunswick and Newfoundland before the 2008 financial crisis pursued low levels of commitment to growing their bioscience industries but shift to mixed levels afterwards.

1.2.2. Independent Variable: Knowledge-Oriented Strategy Team (KOST)

I argue that a *knowledge-oriented strategy team (KOST)* with varying social learning (disruptive or incremental) and iterative bargaining (fragmented or coordinated) characteristics helps explain different types of and changes in commitment strategies. This process occurs especially after a global shock. Decision-makers seek ideas and lessons learned regarding what strategies and institutions are considered both legitimate and effective and combine them with inherited practices and principles in support of new goals. A process of iterative bargaining ensues as to what to do next and how as decision-makers' interests and preferences change in response to the shock. The results fall into high, mixed and low levels of commitment.

I borrow Hall's concept of social learning. It involves state organizations not only acquiring and assimilating information and building competencies but a concerted effort among participants to create mutual understandings about a particular industry, policy, strategy, set of techniques and goals (Hall 1993). I build on Ansell's "project team" in his concept of the networked polity along with Hall's, Bennett and Howlett's understanding of a "knowledge-oriented policy community" as the agent of learning (Ansell, 2000, p. 306; Bennett & Howlett, 1992, p. 285). I re-conceive of it as a *knowledge-oriented strategy team* indicating that strategy precedes policy development. Strategy involves the state and industry assuming roles to learn and build consensus around overarching goals and objectives while tactics involve steps and methods required to achieve them (Stiglitz & Greenwald, 2014). The resulting policy can involve creating new or changing existing formal or informal institutions. The team concept breaks down silos and pulls together disparate strategy networks around common rules and goals.

A strong KOST has multiple and diverse stakeholders including national and sub-national economic development and other relevant agencies, industry associations, local and multinational pharmaceutical and biotechnology firms, service providers, public research organizations, and universities. It is typically led by a government economic development agency or a peak industry association, not elected officials; involves written strategies, work plans with clear time-lines to complete agreed-upon tasks; clearly understood roles and responsibilities assigned to its members; and does not just share information, but improves competencies. Similar to a policy community, a strong KOST survives successive governments. The team is deliberative, flexible, inclusive, and members have clear roles and responsibilities as well as knowledge of latest science and industry trends.

A strong KOST differs from policy networks and communities in that it consciously designs structures enabling it and its members to “learn by learning.” Institutions learn by self-monitoring and engaging in “reflexive” processes that apply institutional memory and intelligence to regular evaluations of goals, tools and processes (Gertler, Wolfe, & Shaw, 2002, p. 3). This social learning process can unleash new ideas, information and ways of doing things while disrupting previous understandings and processes.

A strong KOST is more likely to generate consensus around goals by coordinating the iterative bargaining process. This effort helps to identify opportunities, problems and solutions to them while building competencies. It is a very high bar and ideal-type construction but a useful way to differentiate various types of policy networks and to create a theory of change in commitment strategies.

A weak KOST engages in incremental social learning through regular information exchange rather than competence-building. A non-existent KOST implies that fragmented policy communities or networks drive low levels of commitment. I argue that as the presence and strength of a KOST changes so does its bioscience commitment strategy. Chapter two explains this dynamic in greater detail.

1.2.3 Limitations

A comprehensive analysis of social learning and bargaining would have to analyze dynamics within and among organizations and individuals at all levels (Gertler et al., 2002).The analysis would have to examine learning within organizations like ministries of industry, health or agriculture that aspire to develop bioscience policy; learning among states *and* provinces about how to regulate biotechnology; learning among small biotechnology, large pharmaceutical and service firms around the most effective forms of collaboration; learning among individuals involved in the bioscience industry from VC fund managers to scientists to corporate managers and government industry specialists.

These other levels and actors do impact the bioscience industry. I examine as much as possible the state, industry and university role in a KOST to account for the most transformative type of social learning, Hall's third order that involves state *and* societal coordination around a new policy paradigm. For the sake of clarity and due to space constraints I use this systemic approach while emphasizing the changing role of the state at all levels. My main research goal is to explain the level and degree of change in bioscience commitment strategies while stopping short of evaluating performance.

1.2.4 Hypotheses

This approach enables me to build a theory explaining variation in level of and change in commitment strategies drawing from the existing literature and empirical analysis of cases. I hypothesize that:

Hypothesis 1: A strong KOST in place prior to a global financial crisis is likely to maintain a high commitment strategy afterwards.

Hypothesis 2: A weak KOST in place prior to a global financial crisis is likely to maintain a mixed commitment strategy afterwards.

Hypothesis 3: When no KOST is present prior to a global financial crisis a low commitment strategy is likely to persist afterwards.

1.3 Research Design, Method and Data Collection

To test these hypotheses my research design captures regional variation within Canada. The study combines a most different and most similar systems method to make separate comparisons between the established bioscience regions of Ontario and Quebec and among the aspiring bioscience provinces in Atlantic Canada. Each group of provinces' commitment strategies should be affected similarly and we should expect the jurisdictions to respond in the same way to the 2008 global financial crisis.

While path dependence theorists claim that we should expect commitment levels to change, little is known about how this change occurs and why it varies. I set parameters around the type of institutions examined targeting three: finance, skill development, and corporate governance. Industry acknowledges that all three are critical to bioscience industry evolution and sustainability.

The dissertation applies a comparative, longitudinal case study method to test hypotheses. It uses an inductive approach, letting the evidence from these cases unveil patterns and explanations that are externally valid (George & Bennett, 2005; Glaser & Strauss, 1967; Ragin, 1987).To identify and elaborate causal mechanisms, I apply George's "structured, focused comparison of cases"(George & Bennett, 2005, p. 67). This technique makes theory-building possible as the same questions are asked of each case producing comparable data. Finally, my research errs on the side of capturing complexity and nuance rather than on parsimony and simplicity.

1.3.1 Cases Studies

The research first compares the evolution of bioscience strategies and configuration of institutions across similar federalist countries emphasizing Canada. It broadly compares the changing role of the state and its interactions with industry and the university, their interests, processes of learning about new ways of creating knowledge-based industries and the resulting strategies and institutions. The study then compares and evaluates sub-national cases within Canada using a most similar systems approach. I explore the three critical areas in that bioscience institutions operate: finance, skill development and corporate governance.

The two established regions are Ontario and Quebec. These are large, industrialized economies that drive Canada's growth. They also represent the majority of the country's bioscience industry in terms of number of firms and products. We should therefore expect to see high levels of commitment to bioscience given the provinces' access to resources and the success that each has had in industrializing over decades. But since the 1980s Ontario and Quebec pursued different strategies leading to different bioscience commitment levels.

I chose to compare the four "catch-up" provinces of Atlantic Canada including Nova Scotia, Newfoundland, New Brunswick and Prince Edward Island since they are representative of small, rural regions experimenting with different strategies to catalyze bioscience niche areas. Why did the smallest Canadian province and "crucial case," Prince Edward Island, design and implement a high commitment strategy leading to early signs of industry sustainability (Eckstein, 1975, pp. 94-137)? The three remaining provinces committed at mixed or low levels despite benefiting from the same national institutions like the Atlantic Canada Opportunities Agency and sharing common histories and socioeconomic status.

Including both established and "catch up" regions within a single country case enables me to get the full variation on both independent and dependent variables while holding several variables constant. This approach enables greater control over explanatory variables while facilitating relative independence among cases (Linz & De Miguel, 1966; Snyder, 2001). Finally, this research advances Owen-Smith and Powell's conclusions that "there are multiple pathways to similar outcomes" and not necessarily a "'standard' model of regional innovative success" or failure (Owen-Smith, Powell, & Figures, 2006, p. 5).

1.3.1.1 Why Regional Cases?

Comparative political economy research fails to adequately address institutional disparities related to science-based industries (SBIs) among regions within countries.[6]

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[6]According to the OECD, "A country's science system takes on increased importance in a knowledge-based economy." The science system includes PROs, universities, firms, financial institutions, service organizations and contributes to the key functions of knowledge production, transmission and transfer. The science system's main challenge is in transforming its traditional functions with its newer role as "an integral part of a larger network and system – the knowledge-based economy." (OECD, 1996, p. 21)

Usually these scholars compare national-level data across countries to explain variation in institutional design, technological innovation and industry growth. These data typically include spending on research and development (R&D), the value of foreign direct investment (FDI), intellectual property rights and patent legislation, and, the effects of these variables on technological innovation measured by various indicators including patent counts. Furthermore, even national-level institutions are sometimes the result of negotiating compliance with international regimes such as the Trade-related Aspects of Intellectual Property Rights (TRIPS). So the sub-national level is still ignored.

On the other end of the spectrum, scholars argue that regional institutions facilitate information-sharing and learning among organizations located within close proximity to each other (P. Cooke, 2001). This learning leads to new products, processes and technologies, which sustain long-term growth. Studying regions as a unit of analysis, therefore, is important for three reasons.

First, scholarly research reveals that authority for designing industrial strategies and policies is shifting to or at least shared with regions within countries and across many types of organizations from firms to industry associations to specific government agencies (P. Cooke & Morgan, 1998; Hooghe, Marks, & Institut für Höhere Studien, 2003). Second, regions have become the center of innovative activity, facilitating knowledge-sharing and learning while impacting national-level growth (P. Cooke, Uranga, & Etxebarria, 1998; Saxenian, 1996). Scientists, venture capitalists, biotechnology firms, large pharmaceutical companies and government agency representatives residing in close proximity to each other are more likely to engage in repeated interactions (P. Cooke, 2002; Powell, Koput, & Smith-Doerr, 1996). This behavior can build trust, reciprocity and create social capital that explains variation in levels of industrial growth among regions within countries (Putnam, 1993).

Third, successful regional policies design local institutions such as financial regulations and labor markets to fit industry-specific needs (Locke, 1995; Malerba, 2002). They do not simply implement a one-size fits all national strategy. But national level policies and global networks do have an impact (D. Breznitz, 2007; Edquist, 1997; B. Ä. Lundvall, 1992). National strategies often provide funding, technical assistance and rules governing, for example, intellectual property rights that coexist, coordinate or conflict with local institutions. Ultimately, local individuals and organizations who share similar beliefs about technology objectives make innovation policy (P. N. Cooke, Heidenreich, & Braczyk, 2004; Segal & Thun, 2001).

In addition to bringing regional strategies and institutions into the analysis, evaluating high-tech, innovative industries as opposed to traditional commodity-producing industries is important since scholars recognize them as key drivers for long-term growth in today's global economy (Nelson & Winter, 2002; Niosi, 2000; Schumpeter, 1950). For example, governments invest in bioscience research institutes, university degree programs in microbiology designed to meet industry's labor demands, and R&D grants. At the same time, firms strategically take advantage of these institutions to develop new products, processes and technologies (Gertler & Vinodrai, 2009; B. Ä. Lundvall, 1992; Nelson, 1986; Niosi & Tomas, 2003). This interaction can increase competitiveness and long-term growth as new ideas for products and processes are continually uncovered and exploited.

I argue that evaluating this variation improves our understanding of industrialized and federalist countries' science-based industries as a national composite of regional differences. Not only does it provide insights into why established bioscience regions design different strategies and institutions, but this approach explains why decision-makers in similar, aspiring bioscience regions develop different strategies and institutional configurations conducive or not to industry emergence.

Regional strategic choices can involve whether to dedicate resources in support of niche elements of the product value-chain, like clinical research services, and subsectors such as nutraceuticals and bioinformatics, or, to the entire value chain such as pharmaceutical drug research, development, manufacturing and distribution. They involve the varying ways that regional economic development agencies decide to implement national strategies. Regional institutions range from tax incentives designed to attract FDI to blended national-regional R&D funding, public-private partnerships in new research fields such as genomics, and financing like venture capital funds.

While other comparative political economists have explained varying levels of economic *performance* using a similar research design and applying it to traditional manufacturing industries such as automotive and textiles, few have examined science-based industries like bioscience (Herrigel, 2000; Locke, 1995; Segal & Thun, 2001; Sinha, 2003). Economic geographers have extensively analyzed various factors explaining knowledge cluster emergence and sustainability, from a sufficient knowledge base to second generation entrepreneurs to institutional reforms, but relatively little work has examined the *processes* by which clusters develop and how political interests at multiple governance levels affect them (P. Braunerhjelm & M. P. Feldman, 2006; S. Breznitz, Tahvanainen, & Tutkimuslaitos, 2010; Gertler & Vinodrai, 2009; D. Wolfe & Holbrook, 2000).

Innovation systems scholars debate whether national or regional institutions explain industry growth and whether factors vary among sectors and technologies (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; P. Cooke et al., 1998; Edquist, 2001; B. Ä. Lundvall, 1992; B. Å. Lundvall, 2007; Malerba, 2004). But few weave together these levels and types of analysis to explain how commitment strategies are created in the first place with implications for performance.[7] Opening the "black box" of the political process helps to understand changes in commitment strategies after the 2008 global financial crisis and variation among regions.

1.3.1.2 Why Canada? Comparing Industrialized, Federalist Countries

Canada is a typical case of an industrialized, federalist country that spends a significant amount on bioscience R&D and embraces the "bioeconomy" concept but has difficulty patenting research and innovating products and processes. The country is known for its globally competitive bioscience research base compared to other industrialized, federalist OECD countries. In 2008 Canadian public and private sector investment in biotechnology R&D reached 6.7% and 7.2% of GDP, respectively.[8] These proportions are well above Australia's at 1.3% and 1.1% and similar to the United States'

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[7] I build on Marshall's concept of agglomeration as well as Porter's definition of clusters as, "geographic concentrations of interconnected companies and institutions in a particular field." I use clusters as a way to study their collective impact on the region, though the region is the primary unit of analysis. (Porter, 1998)

[8] See http://www.oecd.org/sti/inno/keybiotechnologyindicators.htm

private sector investment at 7.8%. They are significantly less than Germany's and Spain's public sector spending at 21.2% and 14.2% and Switzerland's private sector investment at 12.6%.[9]

These investment figures do not necessarily correlate with each country's global share of patents, which is an indicator of technological innovation. For example, Australia and Switzerland spend very different amounts on biotech R&D as a percentage of GDP but their global share of patents is the same at 1.6%. I argue that while these R&D investment levels are an important element of a commitment strategy they can lead to policies that rely primarily on R&D spending versus other important factors.

To identify and understand these factors I look to the subnational level where federal and provincial stakeholders interact, creating variation in bioscience commitment strategies. Even though nationally Canada has embraced the promise of a "bioeconomy" and has made significant institutional changes after the 2008 financial crisis to capture new opportunities, these changes do not represent all that is being transformed. Beneath the surface the country's provinces and their stakeholders engage in different types of social learning and iterative bargaining around their own bioscience industry goals and strategies. These dynamics create a national composite of regional differences.

The study pays attention to institutions that provide structure governing federal – provincial relations within the context of the bioscience industry. Canada's federalist constitution prescribes financial support for welfare and income equalization across the provinces, which is an element not found in all federalist constitutions such as the United States'.[10] These rules directly relate to the creation of organizations and mechanisms like the Atlantic Canada Opportunities Agency that provides R&D financing to the "catch-up" provinces of Canada. This study focuses on the three institutional areas of finance, skill development and corporate governance. It more broadly addresses regulations critical to the industry's growth including intellectual property rights. I examine

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[9] Ibid.

[10] Many federations such as Germany, South Africa, Australia, India and others include similar rules that redistribute tax revenue from wealthy to poor subnational jurisdictions, typically states or provinces.

commitment strategies as my dependent variable while uncovering implications for performance.

Canada represents an important, useful case since historically natural resources and traditional industries like agriculture, mining, transportation, oil and gas and tourism have driven its economy. Federal and provincial policy-makers over time created commitment strategies designed to facilitate science and technology-based industries as drivers of economic development. This case enables the researcher to examine drivers of these institutional changes representing different levels of commitment and changes to them before and after the 2008 financial crisis.

While scholars have examined Canadian regional innovation systems related to a variety of science and technology-based industries, none have systematically compared separately *both* groups of established and aspiring bioscience regions over specific phases of development within a single study (Niosi, 2005; Niosi & Bas, 2001; D. Wolfe & Gertler, 1998).[11]Most other countries do not offer the same opportunity to conduct controlled comparisons.

Nor have scholars examined the idea of a KOST and its impact on commitment strategies within this context. To keep the scope of this dissertation manageable, I focus on the role of the state and its interactions with industry, the broader KOST and related policy networks rather than trying to examine every type of actor at all levels and their learning relationships, which would be nearly impossible.

Despite its competitive global position, Canada is a relatively understudied case compared to other countries like Germany, Italy and the U.S. Canada's biotechnology industry is sizeable measured in terms of number of companies, 293 in 2010, which places it 9th after the UK and Australia and before Switzerland and the Netherlands

[11]See Biotechnology Use and Development Surveys (BUDS) beginning in 1996 by Statistics Canada. The first survey, "Survey of Biotechnology Use in Canadian Industries – 1996", assessed the use of biotechnology by selected Canadian industries: Aquaculture and Forestry, Agro-industry, Wood, Pulp and Paper, Coal/Oil/Gas, and Chemicals. Strong indications of widespread biotechnology utilization by the Canadian industry gave rise to the Biotechnology Firm Survey – 1997, 1999, 2001, 2003 and 2005. Surveys from 1999-2005 went beyond measuring the use of biotechnologies to emphasize the development of new products and processes using biotechnology.

(OECD).In addition to being the world's second largest country by land mass it is the world's 11th largest economy with a GDP in 2011 of $1.74 trillion. Canada was the 10th largest economy in the world until 2011 when Russia surpassed it. The above evidence reveals Canada's federalist structure making it conducive to analysis of regional variation in bioscience commitment strategies as well as its significant yet understudied place in the global knowledge economy.

1.3.1.3 Why Bioscience?

The value of the global bioscience industry -pharmaceutical, medical and assistive devices, and biotechnology – is significant. The market for products, services and technologies exceeded $2 trillion in 2010 and is expected to grow to $4 trillion by 2020.[12]Many countries and regions within them, both industrialized and developing, have explicitly targeted the growth of bioscience as part of their industrial policies. Financing is critical to the industry at all stages of product development.

This evidence represents a shared, explicit recognition that a knowledge-based industry like bioscience is likely to yield significant economic and social benefits. Whether or not this is truly the case is debatable (Wong, 2011).Technological, economic and temporal uncertainty in biotechnology all play a role in shaping not only the construction of institutions and organizational structures, but the elusive possibilities for the industry's growth (Wong, 2011).[13]

It is helpful to clarify a few definitions. The field of bioscience is defined as *knowledge gained* from the study of living organisms and applied toward health goals (OECD). Subfields underpinning bioscience range from molecular biology and genetics to biophysics and biochemistry.

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[12] See Ontario Life Sciences Commercialization Strategy – 2010

[13]Wong distinguishes between mitigating risk and managing uncertainty in his analysis of East Asia's attempts to growth a biotech sector. Risk relates to calculated *probabilities* based upon quality information while uncertainty, a step prior to risk evaluation, involves only *possibilities* since within uncertainty there is a lack of quality information upon which to generate probabilities. (Wong, 2011)

Biotechnology, on the other hand, involves the use of *biological techniques* applied to new health research and product development like biopharmaceuticals. The world's first biotechnology drug, a human insulin product called "Humulin" launched by Eli Lilly in 1982, is an example. In particular, biotechnology refers to the use by industry of recombinant DNA, cell fusion, and new bioprocessing techniques. This method contrasts with traditional pharmaceutical development.

In the latter case, firms and their biochemists screen thousands of new chemical entities through a trial and error approach to determine which combinations are effective against disease. Biotechnology, on the other hand, is concerned more with understanding disease mechanisms then developing larger molecules from living organisms to fight the disease.

Since the 1960s, scientists and those involved in the application of biological processes have been shifting from applying biotechnology at the "macro level" – including breeding animals and crops – to the "micro level" - manipulating cells and biological molecules (Guilford-Blake & Strickland, 2008). Using biotechnology at this micro-level to develop products enables a much higher level of specificity, preciseness and predictability, much different from the previous trial and error approaches at the macro level (Guilford-Blake & Strickland, 2008).

The chart below relates bioscience to both its underlying knowledge base with its varied applications.

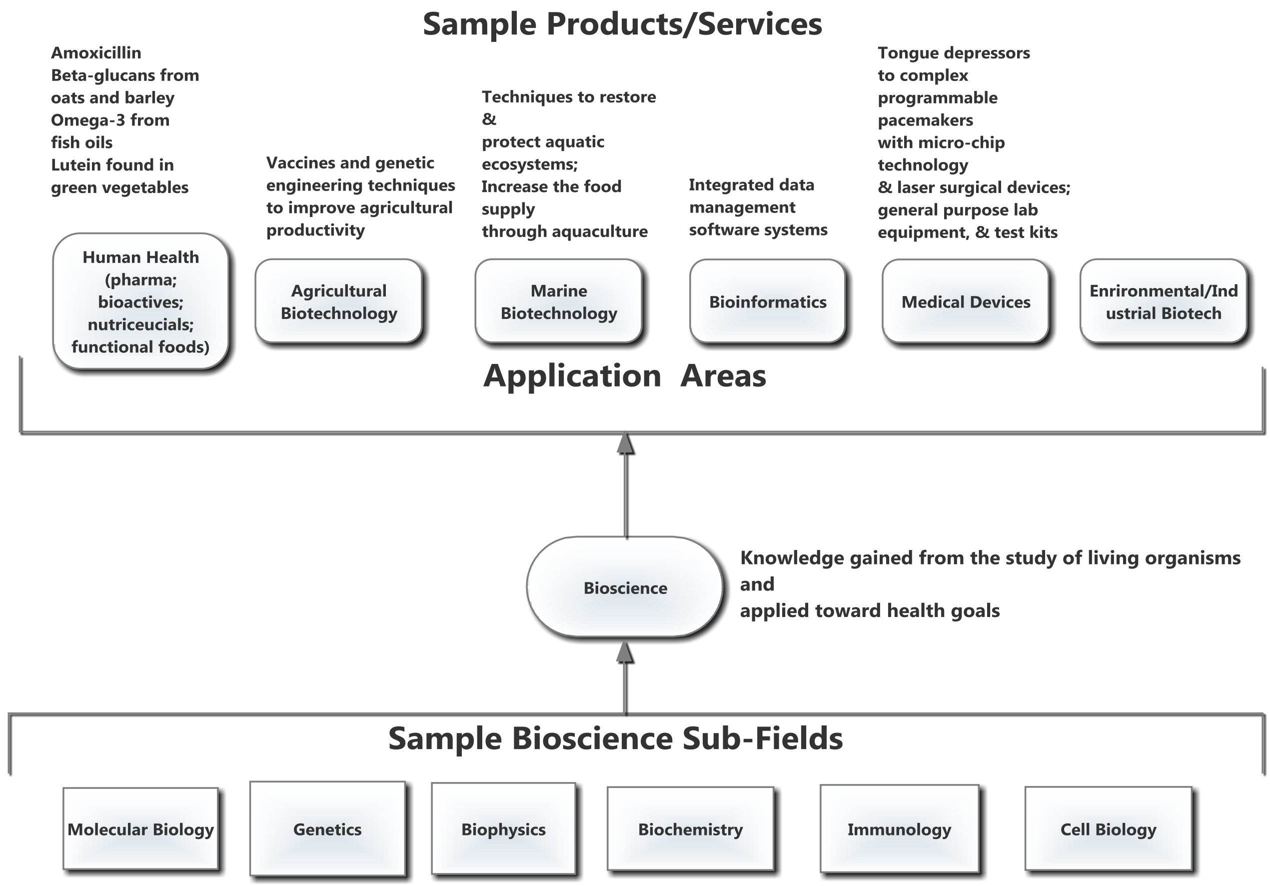

Figure 1. Bioscience Relations to Underlying Knowledge Base and Varied Applications
Source: Data collected and configured by the author.

The table below identifies specific biotechnologies used to develop new therapies for human and animal health, food security, environmental and industrial purposes.

Table 1 List of Biotechnologies

Selection and modification technologies	Recombinant DNA
	Antibodies/antigens
	Peptide synthesis
	Rational drug design
	Monoclonal antibodies
	Gene probe
	Gene therapy
	DNA amplification
Environmental biotechnology	Bioaugmentation
	Bioremediation
	Bio-reactors
	Phytoremediation
	Bio gas cleaning
Culture and use of biological material	Tissue culture
	Somatic embryo genesis
	Bio-processing
	Bio-sensing
	Bio-bleaching
	Bio-leaching
	Microbial inoculant

Source: (Niosi, 2005); Statistics Canada

1.3.1.4 Observation Period: Before and After The 2008 Global Financial Crisis

I chose to examine variation in response to one global shock: the financial crisis of 2008. The choice of this shock is most important since finance is critical to the bioscience industry. Early stage market failures and long product development times require finance at all stages of growth. I first evaluate Canada's, Quebec's and Ontario's bioscience strategy evolution since the 1980s as context. I then compare their commitment strategies just before and in response to the 2008 financial crisis. This approach enables me to capture the change in strategy. For the four aspiring bioscience regions, I only compare their commitment strategy development just before and in response to the 2008 financial crisis. During the 1980s and 1990s these jurisdictions did not have significant bioscience capabilities.

1.3.1.5 Problem-focused Approach

I apply the same set of questions to each case and follow Gourevitch's approach by exploring problem-focused issues and where they intersect (Gourevitch, 1986). In the 1980s the problem was how to create the capabilities to learn the new biotechnologies and how to successfully apply them to agricultural, environmental and health challenges. Over time and during the aftermath of the 2008 financial crisis, the problem became how to leverage scarce resources while still innovating to meet both corporate growth and government economic development goals. This particular challenge involved several sub-issues including how to ensure continuous financing from diverse sources over the product cycle, fill the skills gap in both the private and public sectors, successfully translate basic research into new technologies and how to commercialize them, and managing uncertainty.

I examine bioscience because the majority of developed countries incorporate bioscience in their industrial policies. Bioscience is a broad sector that includes a diverse group of industries that apply knowledge gained from living organisms to improve our health. This is not to be confused with biotechnology, which develops specific technologies based on cellular processes. In this dissertation I use the terms interchangeably as required.

Choosing a more broad-based industry such as bioscience, rather than biotechnology alone, facilitates comparison among subfields. It enables analysis of the political process – social learning and iterative bargaining - involved in deciding which activities should be included in regional and national strategies. These subfields range from agricultural, forestry and marine biotechnology to bioinformatics and bioactives. Comparing countries and regions over two distinct time-periods enables me to determine who learns what and how as well as changes in these.

1.3.2 Data Collection

My primary data-gathering technique involves semi-structured interviews with a representative sample of biotech and pharmaceutical company owners and researchers, provincial and national government bioscience industry specialists, policy decision-makers, national and provincial research institutions, clinical research organizations, industry associations, banks and venture capital fund managers and service providers. Since response rates by bioscience organizations to email, phone and on-line surveys is known to be quite low primarily due to sensitivity of corporate information, face-to-face interviews are the most effective method of securing reliable data.

Between 2010 and 2014, I held 110 interviews in Canada. My many years of experience working with Canadian, Australian and U.S. federal and provincial government agencies on different trade and investment projects some of which related to the bioscience industry inform this dissertation. These interviews are based on a set of predetermined and tested question. They enable not only consistent acquisition of data but the opportunity for interviewees to elaborate on questions of particular relevance. This process often uncovers explanatory variables previously unknown.

Some data was drawn from interviews with individuals who have been active in the Canadian bioscience industry in each province under study and during the timeframe of this study from 1980s to the present. These individuals provided useful information on timelines, critical junctures and institutional change. Other interviews were held with second-generation entrepreneurs, scientists, managers and investors who entered the field over the last 10-15 years. The individuals interviewed specified recent trends in bioscience R&D, financing and organizational management. I collected names of individuals from industry associations, conference organizers and used a snowball technique by asking interviewees for additional references in order to follow conversational threads pertinent to the research.

By attending key industry conferences including BIO in 2010 in Atlanta, SEUS-CP Alliance conference in Raleigh, NC, and BioContact in 2012 and 2013 in Quebec City, Canada I gained greater technical understanding of bioscience and interviewed executives and researchers. I conducted additional industry research with a neuroscientist, bio-psychologist, and biochemist in order to gain greater technical understanding of the field. I reviewed existing survey data collected by Statistics Canada (BUDS), the OECD, USPTO, CIPO and other agencies as well as local and federal government bioscience and industrial policy documents, corporate profiles, and industry publications.

The study involved data collected from a survey conducted with bioscience executives in Prince Edward Island, an aspiring bioscience region. The research team analyzed results using social network analysis. It was more feasible to conduct longer surveys in this region where there are fewer organizations. This analysis enabled me to make conclusions specific to aspiring regions that could be tested with other similar cases such as Nova Scotia.

1.4 Conclusion

1.4.1 Preview of Case Studies

After the 2008 global financial crisis the bioscience industry restructured. The state's role in coordinating economic activity changed. Interventionist states and market-led economies converged towards the "Competition State" and its supply-side support for technological innovation, promotion of open global markets, and power-sharing with industry partners.

Canada and its provinces are useful case studies as they puzzle and power through different ways of creating bioscience commitment strategies. Knowledge-oriented strategy teams at the provincial level play a role in this process. Evidence supports the claim that a strong KOST in place prior to the 2008 global financial crisis maintains a high commitment strategy afterwards.

Canada: Country Context

Canada is known for its strong, globally competitive bioscience research base. Yet like many similar countries, Canada has difficulty commercializing new technologies. The country embraced the "bioeconomy" and made significant institutional changes before and after the 2008 global financial crisis to address this weakness.

Early in the discovery, patenting and commercialization of products using rDNA techniques, Canada, in contrast to other similar states like Australia, sought to aggressively capitalize on the value of the new technology. In 1983 the country established its first explicit biotech strategy, the National Biotech Strategy and its Advisory Committee. A policy community formed around the new science and ways to commercialize technologies to address natural resources and environmental challenges.

Since 1983 the federal government has adapted its strategy to changing domestic and global circumstances. A strategic shift towards human health, new R&D funding mechanisms, a stronger regulatory environment, and the establishment in 2008 of National Centers of Excellence throughout the provinces illustrate the breadth of reforms. But by the early 2000s progress in sustaining the growth of new biotech firms and attracting FDI slowed. The 2008 financial crisis immediately shrunk the number of bioscience firms and risk financing supporting them.

In response, the Harper government in 2012 enacted Canada's latest innovation strategy, "Innovation Canada: A Call to Action." It focused less on basic research and more on public sector-industry collaborations leading to product commercialization. The goal was to improve Canada's economic competitiveness globally by funding collaboration projects with highest potential for commercial success. It was a shift away from Canada's traditional approach of "R&D democracy" involving the spread of financing equally across provinces (McKenna, 2011, p. 1).

A centralization of innovation strategy development was occurring. To tighten links among science, technology, and global economic competitiveness, the government reinstated the Ministry of Science and Technology, which now reports directly to the Prime Minister. This shared common paradigm values commercialization and industry over a previous emphasis on basic university and NRC R&D. In fact, government and industry R&D spending decreased between 2007 and 2012. Even though a shift in overarching goals with a new emphasis on industry collaborations occurred, the reduction in federal R&D funding, disagreements and lack of coordination with the provinces and with basic research advocates may prevent goal attainment.

This research uncovers the nature of changes in the country's commitment strategy. But at the federal level it is beyond the scope of this dissertation to examine in detail the social learning and iterative bargaining processes nationally. The country's provinces engaged in different types of social learning and iterative bargaining to construct their own bioscience industries. Understanding these diverse approaches helps to explain variation in commitment strategies and to form a national composite of regional differences.[14]

Quebec and Ontario

Large, industrialized provinces like Quebec and Ontario should contain the requisite resources and capabilities to capture opportunities offered by growth industries like bioscience. Significant financial resources, many high quality universities and an

[14] Canada is an important case of a country trying to rebalance its traditional industries with knowledge-based ones like bioscience. The Canadian case offers an opportunity to make comparisons at the sub-national level. Regions within federalist countries retain authority to design their own industrial strategies and technological innovation occurs among organizations within close proximity. Furthermore, it is one of the few federalist countries with an income and service equalization clause in its Constitution. Specific federal organizational institutions like the Atlantic Canada Opportunities Agency are designed to help New Brunswick, Newfoundland, Nova Scotia and Prince Edward Island "catch-up" with other wealthier provinces like Quebec and Ontario. I make controlled comparisons among the Atlantic Canadian provinces and separately between Quebec and Ontario.

agglomeration of firms are all present in these provinces. Furthermore, knowledge gained from successfully facilitating the growth of traditional industries like automotive, aerospace, plastics, and agriculture should spillover to new industries (Stiglitz & Greenwald, 2014). However, while Quebec has secured relatively high levels of commitment to sustaining the bioscience industry, Ontario has not. Quebec's strong KOST and previous experiences with public-private partnerships versus Ontario's weak KOST before the 2008 global financial crisis and competing policy communities afterwards help explain this variance.

Atlantic Canada

Because the aspiring bioscience provinces of Atlantic Canada – New Brunswick, Newfoundland and Labrador, Nova Scotia and Prince Edward Island – were all "catch-up" regions during the 1970s and 1980s, none were capable of responding with economic strategies or regulatory changes to the modern biotechnology discoveries at the time. Most relied on previous practices and principles supporting traditional industries. This is not to say that historically the regions did not apply simpler forms of biotechnologies. For example, in 1820 Alexander Keith began making beer in Nova Scotia using the fermentation process. University research in biology and chemistry continued. By the 1980s larger firms along with universities acted as anchors in provinces like New Brunswick in areas of plant science and agriculture.

Today, Newfoundland and New Brunswick suffer from path dependence as vested interests favor innovations in traditional industries such as offshore oil and gas as well as forestry. Others, including Nova Scotia enjoyed early success in bioscience industry growth led primarily by individual firm commitment strategies and some effort by the industry association to develop a broad strategy. However, old paradigms framing the challenge as "states vs. markets" have prevented the creation of a strong KOST and a high commitment to the industry.

The *least likely case*, Prince Edward Island, illustrates why and how a strong KOST can lead to a high commitment strategy. Though some argue that Prince Edward

Island's small size - it is the smallest province by population and land mass in Atlantic Canada - makes it easier to gather stakeholders, deliberate, share information, build competencies, and reach consensus around industry goals, this argument does not stand. Other provinces similar in size, like Newfoundland or New Brunswick especially their largest cities St. John's and Fredericton, have not been able to develop the same high level of commitment.

In addition to the strength of a KOST and multiple policy communities, other variables help explain different levels of and changes in commitment strategies. These include factor endowments, size, rival industries, national institutions, and previous decisions and events. This research explores these variables alongside the presence and strength of a KOST.

1.4.2 Plan of Dissertation

The rest of the dissertation follows the following structure. Chapter two develops the theory further. It defines, conceptualizes and operationalizes the dependent variable, commitment strategies, and independent variable, a KOST. It explores characteristics of a KOST including social learning and iterative bargaining and how these affect its strength. It also explains how the KOST engages in these processes to affect bioscience commitment levels. The chapter explains how the dissertation builds on alternative explanations and again previews case findings.

Chapter three situates Canada in global context. It first explains the role of the "Schumpeterian Competition State" in designing the new bioeconomy. This is important particularly for policy recommendations since many states and regions are experimenting with new roles as they facilitate knowledge-based industries. The chapter compares Canada with the United States and Australia, two other industrialized, federalist countries, and each country's response to the 2008 global financial crisis. The analysis uncovers a convergence around the concept of the "bioeconomy" but divergence of strategies to achieve it. It also provides the context within which to analyze the provincial cases.

Chapter four evaluates the Quebec and Ontario cases representing large, industrialized provinces with significant bioscience assets. It briefly examines how each province developed strategies in response to the 1980s discovery of recombinant DNA techniques in order to capture the benefits of the new technology. It reviews major policy decisions and strategies leading up to the 2008 global financial crisis as well as the actors involved. This section is followed by an in-depth analysis of Quebec and Ontario's commitment strategies just before and after the 2008 global financial crisis. By this time the problem changed toward how to create a common understanding of challenges and opportunities, leverage scarce resources and create competencies. The chapter determines whether or not commitment levels changed and explores the role of a KOST and other variables throughout the process. It provides insights into how large, industrialized regions can either maintain high commitment levels through disruptive social learning and iterative bargaining processes after a global shock, as in the Quebec case, or mixed levels through fragmented policy communities such as in Ontario.

Chapter five analyzes the four aspiring bioscience provinces of New Brunswick, Newfoundland, Nova Scotia and Prince Edward Island in the Atlantic region of Canada. It is similar in structure to chapter four. The *least likely case* of Prince Edward Island and its strong KOST leading to a high bioscience commitment strategy is contrasted against the other three provinces and their low and mixed commitment levels. Natural resources, national institutions, rival industries and size also influenced both the nature of the strategy as well as the level of commitment.

Chapter six concludes by evaluating results of the case studies in relation to the hypotheses established in this chapter. It summarizes why and how a strong KOST prior to a global financial crisis can maintain high levels of commitment to a bioscience industry afterwards. It also explains why a weak KOST or a few fragmented policy communities can create mixed commitment strategies while the lack of a KOST and any significant policy community leads to low levels of commitment to bioscience. The chapter provides implications for theories of institutional creation and change, filling gaps in the comparative political economy literature. It explores policy implications for national and sub-national governments seeking to rebalance their economies to include traditional and knowledge-based industries. It concludes with directions for future research.

CHAPTER 2

THEORETICAL FRAMEWORK:

"PUZZLING AND POWERING THROUGH"

2.1 Introduction and Theory

In this chapter I present a theoretical framework explaining the way that commitment strategies related to science-based industries develop after a global shock. Opening this black box facilitates greater understanding of what the specific governance mechanisms are for transmitting ideas, information, knowledge, and building consensus around the way forward. This activity can lead to high (holistic), mixed or low levels of commitment to industry goals. Understanding this process and the factors that drive it is important as they create different trajectories with long-term effects. These consequences can be positive in terms of stabilizing the industry while capturing opportunities or negative by remaining trapped in outdated, ineffective institutions.

The dependent variable is *commitment strategy*. The independent variable is the *knowledge-oriented strategy team* (KOST). I argue that the presence or not and strength of a KOST helps to explain variation and change in commitment strategies. The degree to which the KOST engages in the process of social learning and iterative bargaining influences the level of commitment. I conceptualize social learning as either disruptive or incremental. The iterative bargaining process can be either coordinative or fragmented. These components comprise a political process that impacts commitment strategies in response to the 2008 global financial crisis. The framework below illustrates this process.

Figure 2 Theoretical Framework

2.2 Variables and Measures

Governing a bioscience industry compared to other technology-based industries like ICT is difficult. The high level of uncertainty, rapid innovation and many scientific disciplines, application areas and actors involved create distinct challenges. Pharmaceutical multi-national corporations (MNCs), biotech start-up firms, clinical research organizations, hospitals, universities, government agencies, patient groups, venture capitalists and various service providers all carry distinct knowledge domains creating a potential source of technological innovation. But these stakeholders also bring competing interests.

Actors like state agencies or industry associations respond to this challenge by developing strategies and institutions in order to help individual organizations capture opportunities that they could not on their own. In bioscience the most significant institutions include formal and informal rules governing finance, skill development and corporate governance. These institutions are detailed in Table 2. Rules range from R&D funding to training programs to corporate "make or buy" decisions. Attempts to govern these complex forms of economic organization among groups often fail because of information asymmetries, competing interests, potential opportunism, or incompatible time-lines (Alleva-Caceres, 2014; Milgrom & Roberts, 1992).

Prior to creating institutions states typically generate formal strategies and plans that inform which institutions are created, changed or decommissioned. Despite this trend not all countries and regions design formal strategies and even those who do often end up not implementing them. Some take a more tactical approach changing levels and types of investment in finance, skills and corporate governance but do not change overarching goals. All represent different levels of credibility and commitment towards capturing the benefits of the new technology while minimizing its risks. Table 1 defines commitment strategy, the KOST as well as its key characteristics, how these are measured and related literature.

Table 2 Variables and Measures

Variable	Characteristics/Claim	Measures/Indicators	Literature
DV			
Commitment Strategy	Comprised of goals, techniques and settings (e.g. amount of R&D investment) in three institutional areas of finance, skill development and corporate governance. Commitments are specialized; difficult to reverse; result from repeated interactions; create trust; facilitate information/knowledge/resource-sharing, more certainty, help reach individual and collective goals.	High (Holistic) - Institutional complementarity Mixed Low	(P. A. Hall, 1993; P. A. Hall & Soskice, 2001; Morgan, Campbell, Crouch, Pedersen, & Whitley, 2010; D.C. North, 1990; Williamson, 1983)
IV			
Knowledge-Oriented Strategy Team (KOST)	Deliberative, flexible, inclusive – knowledge of previous policies/institutions latest science & industry trends. Varying Characteristics:	Strong, Weak, None	(Ansell, 2000; Bennett & Howlett, 1992; P. A. Hall, 1993; Rhodes, 2006)
	Social Learning: Involves Information acquisition, assimilation and competency-building + concerted effort to create mutual understandings about a particular industry, policy, strategy, set of techniques and goals.	Disruptive, Incremental	(Gertler et al., 2002; P. A. Hall, 1993) (Bennett & Howlett, 1992; P. Cooke, 2001; McDermott, 2007; McDermott & Corredoira, 2010)
	Iterative Bargaining: Political bargaining model; Actors with *both* competing and complementary interests can make room for cooperation; negotiating occurs regularly in light of new information.	Fragmented, Coordinative	(Dunning, 2001; Eden, Lenway, & Schuler, 2005; Quirk, 1989; Schelling, 1980)
Control Variables & Alternative Explanations			
Factor Endowments	Natural& human resources, specialized infrastructure impact commitment strategy level and type (e.g. focus on bioactives vs. bioinformatics)	Type of natural resource; infrastructure	**[add here] Powell etc.**
Size	A jurisdictions size affects commitment levels. Easier for smaller jurisdictions to commit than it is for larger provinces given higher number of competing interests.	# firms, population	Uzzi
Rival Industries	Traditional industries compete for resources; related institutions incompatible with knowledge-based industries.	Automotive, agriculture, plastics, ICT	
National Institutions	National institutions shape provincial strategies. Not all provinces implement national strategies similarly.	S&T/Biotech R&D funding; IPR; PROs & their core knowledge areas	
Global Shock	2008 Global Financial Crisis. Affected majority of countries/regions.	Sudden scarcity of finance	
Path Dependence	Previous decisions and related institutions resist change; vested interests; institutional change occurs only after major shock then new equilibrium reached.	How actors react to GFC in light of previous industrial policy decisions and new information	(Mahoney, 2000; Mahoney & Thelen, 2009; Thelen, 1999)

2.2.1 Dependent Variable: Commitment Strategy

My dependent variable is “commitment strategy” including both the *change in* and *degree of* commitment. I conceive of commitments as institutions that have been created or changed as part of a larger strategy to develop a bioscience industry. Critical institutional areas in bioscience include finance, skill development and corporate governance.

Institutions act as credible commitments necessary to facilitate low-cost transactions. They are specialized, difficult to reverse, and include incentives aligned with the skills and knowledge perceived to offer the highest payoff (Kreps, 1996; D. C. North, 1993). In other words, given the rising complexity of the science and nature of the industry it is too costly for bioscience organizations to act alone. Formal and informal rules that enable organizations to capture new opportunities at a lower transaction cost are necessary. I apply nominal measures including high, mixed and low levels of commitment to developing a bioscience industry. These commitment strategies can change in either direction or not at all especially after a global shock.

Creating and maintaining long-term *credible commitments* among bioscience stakeholders is difficult. I borrow the credible commitments concept from the institutional economics literature. This research stream focuses primarily on firm-firm level commitments. I expand it to include a broader array of organizations including multi-level government agencies, industry associations, leading MNCs and local firms, universities and other stakeholders. These commitments require “irreversible, specialized investments” involving “reciprocal acts” designed to support alliances and exchanges more efficiently (Williamson, 1983, p. 519).[15]

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[15]For example at the firm level, Biovectra, Inc. is a contract manufacturer of active pharmaceutical ingredients and the largest local firm based in Prince Edward Island (PEI), Canada. To expand its innovative manufacturing process in support of global partner needs, the province provided a portion of funding required over the course of 10 years that BioVectra, Inc. leveraged to secure a U.S. investor, Questcor Pharmaceuticals. These investments are considered specialized and represent reciprocal acts among Biovectra, Inc., provincial and federal funding agencies - Innovation PEI, ACOA, and a foreign direct investor, Questcor Pharmaceuticals.

Table 3 Sample Elements of Bioscience Commitment Strategies[16]

Rule Category	Formal Mechanisms	Formal Rules	Informal Rules/Norms
Finance	• Gov't R&D grants Tax incentives (FDI, local) • Gov't-backed & Privately owned Venture Capital (VC) funds	• Rules governing use of R&D incentives	• Gov't has an obligation to invest in basic, applied and/or commercialization projects • Markets allocate finance to the most promising therapies • R&D Spending should focus on university research.
Skill Development/Acquisition	• Gov't tax incentives- labor; immigration policies • University degree programs • Corporate training & hiring policies	• 100% tax credit per local scientist hired; • Ratio of local/foreign hires (immigration policy)	• Corporate hiring practices favoring local over global scientists • Flexible labor market
Corporate Governance	• Contracts • Ownership and management governing mechanisms	• "Make" or "Buy" decisions • Rules governing stockholder and management interests	• Transparency in governance model (owners/managers) • Informal alliances among organizations to build competencies

[16] Mechanisms are somewhat different from the rules themselves. Formal mechanisms involve specific programs and processes through which agents implement rules. Informal mechanisms include learning and information sharing through various channels like networks and collaborations producing shared beliefs and understandings. Formal rules prescribe or proscribe certain behavior while informal rules are understood as accepted norms of behavior.

2.2.1.1 Generating Commitments: Roles, Incentives and Relational Contracts

Williamson's definition of a credible commitment does not include the need for a shared understanding of who takes on which tasks, incentives to engage or renege, and consensus around the way forward. The political process neither guarantees getting there, nor ensures that actors can maintain what is necessary. This dissertation explores how actors establish credible commitments as part of a strategy to expand the opportunity structure, reduce uncertainty, and encourage risk-taking behavior among organizations?[17] The role of a KOST is central.

North's analysis asks how can institutions provide the credible commitment necessary to facilitate low-cost transactions (Kreps, 1996; D. C. North, 1993). In other words given the complexity of the science and nature of the industry it is too costly for bioscience organizations to act alone. Formal and informal rules that enable organizations to capture new opportunities at a lower transaction cost are necessary instead. These institutions will include incentives that are aligned with the skills and knowledge perceived to offer the highest payoff.

Williamson's understanding can shed light on the high level of risk and uncertainty associated with an industry like bioscience. His key characteristics of credible commitments involve irreversible, specialized investments and reciprocal acts (Williamson, 1983). For example when government invests in specialized research centers, like the Institute for Marine Bioscience in Halifax, NS or Genome Quebec as well as in R&D related to specific disease areas like cancer or Alzheimer's and firms reciprocate by matching investments over time, these repeated interactions evolve into social norms around what are considered credible commitments for the industry.

The critical challenge is designing *beforehand* the most efficient and effective incentive scheme especially since it is almost impossible to know in advance all the possible risks associated with an alliance. Firm-firm relations and public-private sector

[17] I thank Steve Casper for making the author aware of the concept of credible commitments as well as relational contracting within the institutional economics literature.

partnerships confront this challenge especially when building a bioscience industry that is by nature highly uncertain and risky.[18]

Gibbons and Henderson elaborate the challenges associated with both incomplete contracts and credible commitments. The problem is that there is no way to specify all contingencies in a written contract. These scholars emphasize the need for clarity and understanding of promises as a critical element of credible commitments in order to reduce uncertainty. However, the process of achieving it is extremely difficult (Gibbons & Henderson, 2012).This again is where a centralized industrial governance structure can help by anchoring a government agency or industry association to aggregate interests, clarify roles and responsibilities, and facilitate repeated interactions. Reducing uncertainty is central to economic reform and growth.

Getting this approach right is not pre-determined. Maintaining industry sustainability amidst complexity is the central challenge to all bioscience clusters. Legal scholars and sociologists have argued that *relational contracts* underpinned by trust and social norms are important in generating commitment to relationships (Macneil, 1978). Empirical studies support the relational contracting view by showing that social norms rather than explicit legal provisions frequently structure economic behavior between parties (Ellickson & Ellickson, 2009). Within intricate, long-term relationships, parties can develop social strategies to achieve cooperation, often resulting in the creation of credible commitments not to behave opportunistically (Kreps, 1990; Miller, 1993). Examples include the creation of a reputation not to exploit weaker parties or 'signaling' strategies

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[18]For example, during late 1990s and early 2000s, mapping the human genome was a major goal for the global bioscience industry. Research and technology had advanced to the point where mapping at least a segment of the genome was close at hand. Governments at both the provincial and federal level as well as big pharmaceutical firms invested in new research centers like Genome Quebec with the promise of making break-through discoveries leading to a plethora of technologies to be commercialized, creating economic wealth and highly skilled jobs in the province. However, while in 2003 scientists in the United States succeeded in mapping the human genome, the new knowledge did not lead to the blockbuster biotechnologies or drugs personalized to groups with particular diseases. Anyone can now take a blood test, have the results analyzed and receive information on which disease-carrying genes they have – from Alzheimer's to various cancers. The tests are now so simple and relatively affordable that the service has become a commodity and considered a weak source of regional competitive advantage. Furthermore, scientists have learned that the science behind the study of genomics is much more complex than originally thought. Therefore, developing cost-effective therapies for particular diseases based on the science at hand is still time-consuming and costly.

such as making contingent investments in relationship-specific assets with the expectation that one's contracting partner will reciprocate, allowing norms of cooperation to develop (Axelrod, 1984; Casper, 2013).

Relational contracting is problematic despite these possibilities. Managers find it difficult to get the organization to establish and implement commitments in a way that is clear to other parties. Do the parties *understand* what they have promised? Credibility and clarity could also interact in different ways making it difficult for organizations to build both (Gibbons & Henderson, 2012). It is not easy to specify all the necessary actions in advance because relational contracts are informal and collaborative (Gibbons & Henderson, 2012). Building a relational contract is difficult for all these reasons. To do so it takes a shared understanding among the parties of their required tasks as well as the potential for and consequences of reneging (Gibbons & Henderson, 2012).

A *knowledge-oriented strategy team* (KOST) can help address some of these challenges. I argue that the presence of a strong KOST is a major factor driving high levels of commitment to cultivating and sustaining a bioscience industry. A strong KOST can build credibility through relational contracting among organizations and can generate spillover effects to the broader community. This relational contracting can change social norms in support of collaboration projects among organizations, promises not to renege on agreements, and learning structures.

2.2.1.2 Separating "Commitment Strategies" from "Social Learning" and a KOST

I treat commitments as institutions. These formal and informal rules can vary and change in different directions or not at all when a KOST engages in different magnitudes of social learning and types of iterative bargaining. I draw from Hall's orders of social learning and their relation to policy change to capture change in commitment strategies. The following table provides expanded definitions and examples for each order.[19]

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[19]Since institutions can be understood as policies that have endured over time, the approach is useful.

Table 4 Orders of Social Learning and Indicators of Policy Change

	Description/Definition	Example	Magnitude of Social Learning
First Order	Changes in settings of particular policies.	A change in bioscience R&D spending levels.	Incremental
Second Order	Changes in both settings and techniques - or policy tools.	A change in both R&D spending levels and shift from R&D tax incentives to incentives for industry-backed VCs.	Incremental
Third Order	Changes in settings, techniques and overarching goals	A change in the above plus shift in basic research to commercialization and industry collaboration projects.	Disruptive

Source: Peter Hall and Examples Selected by the Author

First order learning is reflected in changes in settings like R&D spending levels. Second order learning is reflected in changes in techniques or the tools used to disburse funding like government-backed VCs or grants. Third order learning relates to changes in overarching goals underpinned by a paradigm change such as shifting from basic research to university-industry collaboration projects with the goal of improving technology commercialization.

First and second order learning involves mostly the state as decision-maker. Third-order learning represents a fundamental paradigm shift involving stakeholders within both the state *and* society interacting through a knowledge-oriented policy community (P. A. Hall, 1993). This community frames the problem, the types of commitment strategies designed to solve it, and builds consensus around the way forward. Social norms change in order to take advantage of the new opportunities during this process. However, it is the most difficult type of learning and policy change to achieve considering the range of often conflicting interests.

Hall's approach reveals weaknesses. He creates a tautology by not clearly separating social learning indicators from those of policy change (and it follows, change in commitment strategies). Hall argues that we know that communities learn when we see a paradigm shift or change in core beliefs as well as in overarching goals, not just changes in settings and programs that are part of the normal policy process. By definition major policies change when fundamental social learning occurs but the same indicators are used for both the independent and dependent variables. Furthermore, he does not clearly define "who learns."

I create new indicators of social learning to solve this problem and associate them directly with the KOST as the independent variable. I argue that the presence or not of a KOST and its relative strength leads to different levels of commitment towards bioscience industry development. I am also explaining the direction in which commitment strategies *change* before and after the 2008 financial crisis. For example, what causes a change from a mixed to high level commitment is the change in relative strength of a KOST from weak to strong defined by indicators such as inclusiveness, deliberative nature, flexibility, and competence-building.

In the next section I elaborate on the dependent variable: Commitment strategies. I structure commitment strategies as high, mixed and low along with related indicators. The case studies evaluate how commitment strategies can change from one category to another over time. This section is followed by an examination of the KOST and its social learning and iterative bargaining characteristics.

2.2.1.3 Typology of Commitment Strategies

I argue that the presence and strength of a KOST impacts both the level of commitment and change, if any, in it before and after the global financial crisis.

High Commitment Strategy[20]

I define a high commitment strategy as one where institutional complementarity in areas of finance, skill development and corporate governance exists. Each area includes

[20] I am grateful to Steven Casper for his elaboration of the "High Commitment Strategy" concept. I expand it by including both the state and firm-level commitments.

formal and informal rules designed to reach shared, overarching goals. This complementarity represents a more holistic and strategic approach in support of bioscience industry goals.

A strong KOST is established credible commitments among members. The commitment each makes to a new bioscience strategy is specialized, difficult to reverse and entails repeated interactions over time. This process builds trust, facilitates information-sharing, improves competencies, reduces uncertainty and creates relationships that help individual and collective goal attainment. This process also changes the mindsets of state and society participants towards a learning culture resulting in fundamental changes in overarching goals.

Categories of actors involved in this process include private sector organizations such as small biotech firms, large pharmaceutical MNCs, manufacturers and professional service providers, public agencies pursuing varied objectives from improving human health to promoting economic development, and universities and medical schools engaging in science and health research. Actors can form a single or a few knowledge-oriented policy communities depending upon the level and type of shared understandings about bioscience and its promise. Often either the state or an industry association initiates the process. But *managing* the process of establishing credible commitments is complicated and often does not work due to information asymmetries, competing interests, potential opportunism and incompatible time-lines among actors.

If successful, the rules and norms themselves reflect mutual understandings of what the specialized, irreversible investments as well as repeated interactions among actors should be and are reinforced by this dynamic. The process is influenced by the relative strength of the KOST.

For example at the firm level a “high commitment” strategy entails a sophisticated FDI firm not only entering a local bioscience cluster like Montreal or Halifax, but also engaging in higher value activities (e.g. R&D) and participating in local cooperative networks when doing so. It is this type of behavior that could lead to the upgrading of capabilities within a cluster. But since bioscience clusters are rare, what prevents experienced firms from engaging in high commitment activities within an emerging cluster?

The institutional economics literature can help frame the commitment issue facing actors within emerging clusters (Milgrom & Roberts, 1992). This literature claims that complex forms of economic organization often fail because parties cannot develop adequate formal or informal governance rules needed to overcome a variety of dilemmas (Miller, 1993). Cooperative R&D networks are inherently failure prone largely because of unforeseen scientific challenges but can also fail due to a lack of commitment by one of the parties, poor social skills by one or both parties (i.e. difficulties in successfully participating within a collaboration), and fear of intellectual property expropriation. (Casper & Matraves, 2003). While contracts can be written setting out basic rules over funding, the division of labor, and intellectual property rights within R&D projects it is difficult to write contracts specifying all contingencies.

Governments confront some of these same challenges especially when engaging with industry and universities. A disruptive social learning approach combined with a coordinated bargaining process can unleash new ideas and create social norms about how to achieve collective goals. At the same time the interaction can help to solve some of the commitment and credibility problems.

2.2.1.3.1 Indicators: Level of commitment strategy: A high commitment strategy equates to institutional complementarity (holistic approach) among finance, skill development and corporate governance at all levels of settings, techniques and overarching goals. A holistic approach involves a paradigm shift favoring change in overarching goals within and coordination across all three institutional areas. These can include diversifying financial sources, developing interdisciplinary skills to align with industry needs; and promoting FDI-local firm collaboration in order to create learning spillovers necessary for industry sustainability. A change in *nature* of these formal and informal institutions in response to the 2008 financial crisis can still occur while maintaining institutional complementarity.

2.2.1.3.2 Indicators: Change in level of commitment strategy. If a high commitment strategy was in place prior to the 2008 financial crisis, then I capture no change or a change to mixed/low levels by comparing whether institutional complementarity broke down after the crisis

Mixed Commitment Strategy

A mixed commitment strategy includes complementarity between two institutional areas like corporate governance and finance but not a third such as skill development. A weak KOST may have established its credibility within a region through repeated interaction in developing financial markets and corporate responses to them. This effort can result in increased levels of R&D funding and diversification of risk finance vehicles. However, the same level of commitment may not be made in the critical area of skill development because of a lack of knowledge about what skills are required by industry, competing views of the importance of basic versus applied research, and whether to invest in high-potential R&D versus "R&D democracy" that spreads funding more broadly.

In this sense a lack of consensus around the way forward in skill development may reduce effectiveness of changes made in finance. Furthermore, firms may choose to outsource more R&D thereby decreasing internal R&D spending and the need to train scientists and portfolio managers. A mixed commitment strategy lacks credibility and constrains the region's ability to develop necessary governance rules. But short-term gains in industry growth can occur. The strategy can also signal progress in certain areas and an expectation that complementary changes will be made as a result of the social learning and bargaining process in other bioscience areas.

2.2.1.3.3 Indicators: Level of commitment strategy. Institutional complementarity between two types of institutions but not all three.

2.2.1.3.4 Indicators: Change in level of commitment strategy. If a mixed commitment strategy were in place prior to the 2008 financial crisis, then I capture no change or a shift to low/high levels by comparing whether or not institutional complementarity existed after the crisis.

2.2.1.3.5 Low Commitment Strategy

A lack of institutional complementarity among the three areas equates to a low commitment strategy. In this case the commitment may include government but not firm R&D investments and no new university degrees designed to attract or produce bioscience skills required to conduct R&D effectively.

A low commitment strategy involves a few actors, typically state agencies, setting the rules and making simple changes in investment levels and types. Incremental social learning and fragmented bargaining underpin the process. While some investments in hard infrastructure may be made, these are non-specialized and reversible investments with little effect on alliances among firms particularly between sophisticated FDI and small, local biotech firms or on public-private partnerships. The rules and norms of the game may change but they represent low level commitments. This type can generate short-term industry growth but often follows a path dependent trajectory in a negative direction.[21]

For example, to attract FDI governments routinely locate companies and provide incentives such as tax credits, subsidies, and access to low rent land and infrastructure. In bioscience, governments commonly set up incubators and technology parks on or near universities with the promise of enticing entrepreneurial new technology firms to take up residence. Companies often respond positively to such incentives, particularly if basic factor advantages such as access to relatively low cost labor exist within a region. But these MNCs do not always actively engage in collaborations with local biotechnology firms, reducing knowledge and technological spillovers as well as opportunities for local firms to upgrade. While some MNCs engage in low levels of commitment, governments

[21] Here I rely partially on Hall's indicators.

that create favorable R&D environments through infrastructure investments and tax policies often view their strategy as a high level of commitment. Governments are also pressured to attract FDI while growing the local biotechnology cluster. The gap between the two can be filled by improving relational contracting capabilities between public and private sector organizations.

2.2.1.3.6 Indicators: Level of commitment strategy. No institutional complementarity. Elements tend to include traditional university R&D, investment in hard infrastructure, government grants to firms but little monitoring.

2.2.1.3.7 Indicators: Change in level of commitment strategy. If a low commitment strategy was in place prior to the 2008 financial crisis, then I capture no change or a shift toward mixed/high levels after the crisis utilizing indicators associated with these levels.

<u>2.2.1.4 Selected Bioscience Strategy Choices</u>

Governments and industry face a strategic choice set when it comes to the creation of new institutions to help reach bioscience industry growth goals. These range from basic research versus technology commercialization to horizontal versus specialized R&D to FDI-led versus local industry development. Governments must navigate the puzzle of appearing to "pick winners" versus letting markets allocate resources toward the most productive R&D areas. Often it is some combination of the two.

Governments must also ask the question: How formal and how specific should the strategy be? In bioscience strategy development should the country or region focus on facilitating platform technologies[22] with broad or narrower application areas like

[22]In biotechnology and pharmaceutical development, platform technologies help drug firms discover, identify, process and develop new chemical entities more quickly and efficiently. The platforms range from large chemical libraries and ultra-high throughput screening to genetic databases in discovery and predictive toxicology platforms, to specialized knowledge of particular therapeutic areas. Small, virtual biotech firms can more easily ascertain the transaction cost associated with developing their own platform technology, or, outsourcing and using a platform developed by others. Large pharmaceutical firms typically maintain their own in-house, proprietary and sophisticated platform technology. While

genomics or nutraceuticals? Under what circumstances can states create new institutions to help capture new opportunities while reducing costs, uncertainty, and risk? Social learning and a coordinated iterative bargaining process involving the triple helix of government, industry and university research can unleash new ways of solving the problem and lead to more informed strategy choices.

I argue that a key factor that helps facilitate the learning process is the presence and relative strength of a KOST. A KOST is typically led by an industry association or economic development agency whose members are firms, governments at all levels, university and other societal representatives. A KOST becomes critical as its volunteer membership represents the general bioscience ecosystem and can bring diverse perspectives to bear.

For example in industry big pharmaceutical firms and small biotechnology companies differ in their business models based on the drug development processes. Big pharmaceutical firms cannot copy asset-centric drug development activities that small biotech firms do. Pharmaceutical MNCs maintain large platform technologies that are used to develop multiple drugs, not just one. Society may pressure government to fund new research into vaccines that inoculate against disease but industry may be reluctant because of insufficient market size. Universities may favor basic cancer research rather than collaboration with industry due to conflicting time-lines. Yet these initial interests shaped by participants' cognitive frames can change through the social learning process. Repeated interactions, talk, communication among stakeholders, building competencies and negotiation around the way forward can shape commitment strategies.

A major challenge involves how to facilitate learning spillovers. Industrialized countries typically host significant FDI. This is true as well in the bioscience industry as large, incumbent pharmaceutical firms expand their technological base by acquiring or merging with biotechnology firms or investing in in-house bioscience R&D. But it is far

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these systems are expensive to maintain and difficult to value return on investment, platform technologies are a complementary asset not easily replicated by competitors. Increasingly, though, big pharma and small biotech firms are forming pre-competitive consortia to keep platform technologies cutting edge. These new institutions involve rules and norms that stipulate how resources are shared, each member's role and responsibility and how opportunities are secured and costs reduced.

from given that FDI will engage with local start-ups or create positive spillovers including the sharing of ideas, information and technologies as well as the expansion of highly skilled labor that could sustain industry growth. Local firms may not share the same level of sophistication in their ability to collaborate or their assets may not be valuable enough. Even small firms that succeed in developing a new chemical entity (NCE) like a new fish anti-freeze protein in Newfoundland often license out the new technology to a foreign buyer only to see jobs created elsewhere.

There are two challenges. The first involves finding a way to entice FDI while transferring skill, technologies and financing to grow and sustain the industry. The second includes creating environments for local start-up firms to grow toward medium-size and stay. These two goals are interrelated as the more medium-sized local firms there are in a particular jurisdiction the greater the likelihood of attracting FDI. MNCs are more likely to effectively collaborate with experienced local firms, transferring skills and technologies along the way.[23]

2.2.2 Independent Variable: Knowledge-Oriented Strategy Team (KOST)

I define a strong KOST as a group comprised of multiple and diverse stake-holders typically national and sub-national economic development agencies, industry associations, local and multinational pharmaceutical and biotechnology firms, service providers, public research organizations, and universities. Members have clear roles and responsibilities as well as knowledge of the latest science and industry trends. An anchor organization, often an industry association, leads the strong KOST. The team is deliberative, flexible, inclusive, creates strategy and work plans with clear time-lines and builds competencies over time.

I provide a list of indicators in Table 3. First, I determine whether or not a KOST is present in the cases analyzed. If yes, then I determine whether it is *strong or weak*, indicated by the way in which it engages in the social learning and iterative bargaining

[23] Author Interviews, Toronto, Ontario, March 25 2014; Montreal, Quebec, November 2012; St. John's, Newfoundland, March 2014; Charlottetown, Prince Edward Island, June 2013.

process. A strong KOST is inclusive, flexible, deliberative and engages in disruptive social learning and coordinated bargaining processes. The social learning process is disruptive as the KOST continually monitors, collects, disseminates, deliberates and acts on new information and ideas about the industry and reflects on the effectiveness of its previous commitment strategy. Its own competencies change, displacing old ways of thinking and approaching problems, which has spillover effects among its members who also design their own organizational strategies. With this intentional and consistent approach to accessing the latest information and ideas about the industry and how to sustain it, the process results in a more holistic, high level commitment strategy.

A weak KOST engages in some of the same activities as a strong KOST except that it pursues them irregularly, has weak channels of cooperation and does not build competencies. The focus is more on information-sharing. No KOST exists when few of these attributes are present. However, a region with no KOST can still have multiple policy communities, each engaging in its own learning and bargaining process. These processes involve competing interests with no consensus around strategy, goals and institutions required to reach them. If there is no KOST, then the region is likely to provide only lower level commitments to the industry consistent with a normal policy process.

Table 5 Who Learns What?

Who learns: KOST	Indicators	Sources:
Knowledge-Oriented Strategy Team (bioscience)	Strong: -Clear structure and mechanisms for information-sharing and competence-building. Creates a "learn-by-learning" mindset and structure. -Inclusive, deliberative (state-society actors) -Anchor organizationecon. dev. agency/industry assoc. -Written strategic and work plan -Regular meetings; monitoring, evaluation, change in light of new information -Access to formal knowledge networks -Agents with clear roles and responsibilities Weak: Irregular monitoring, evaluation Few channels of cooperation Focus on information-sharing, less on competence-building	Key policy documents;interviews; committee reports; surveys, policy reports, industry studies, excerpts from official statements
What is learned:		**Sources:**
Ideas: Core beliefs, strategy goals, and means of implementing them Ex: Science underlying bioscience industry; assumptions about the industry; how to frame the problem; what goals to set; what has worked in the past and in other jurisdictions, and what has not; new models for organizing economic activity; how to implement effectively; how to build competencies		Interviews Surveys Industry studies Policy documents Technical reports

2.2.2.1 How Does a KOST Differ from a Policy Community and Policy Network?

Other more traditional means of information-sharing and consensus-building do exist, some of which contain elements of a social learning structure. Many countries and regions sustain various policy communities and networks. In policy-making both involve relationships among actors whether individuals or organizations but “vary along a continuum in terms of the closeness of these relationships” (Rhodes, 2006, p. 427). Policy communities are at one end of the spectrum and encompass close relationships while networks are at the other end with relatively loose relationships.

According to Rhodes a policy community typically involves:

> A limited number of participants with some groups consciously excluded; frequent and high-quality interaction between all members of the community on all matters related to the policy issues; consistency in values, membership, and policy outcomes that persist over time; consensus, with the ideology, values, and broad policy preferences shared by all participants; and exchange relationships based on all members of the policy community controlling some resources. Thus the basic interaction is one involving bargaining between members with resources. (Rhodes, 2006, p. 427)

A network is “complex and dynamic; there are multiple, over-lapping relationships, each one of which is to a greater or lesser degree dependent on the state of others”(Elkin, 1975, pp. 158-184) . Policy networks mediate interests, enable inter-organizational analysis and are a form of multiplex governance especially in contrast to traditional hierarchical forms led by central governments.

Different policy communities often numbering up to four and associated with a single issue can exist within a country or region (Sabatier, 1988). These communities compete among each other rather than coalesce around common goals and means of achieving them. For example, in Newfoundland a policy network has developed in the area of health information technology with the explicit goal of improving patient care and access while maintaining privacy. Another policy network strives to grow the industry in niche areas of bioinformatics and marine biotechnology in order to increase the number of firms and well-paying jobs. The two goals are not always seen as compatible. In the area of environmental biotechnology two competing networks exist. One strives to develop new products based on bioactives derived from plants and trees while the other pursues completely different goals including forest preservation.

A strong KOST shares some characteristics of a policy community but differs in several ways. First, because I am interested in understanding industrial policy and specifically how regions develop commitment strategies towards growing knowledge-based industries the anchor organization in this highest form of policy network is either a government economic development agency or a peak industry association. It is not led by regional elected officials. The industry association typically plays a coordinating, catalytic role while government agencies at all levels are partners and in many cases provide financial and technical resources.

Second, a strong KOST is more inclusive than a traditional high-level policy community. All relevant government agencies, universities, research organizations and firms can become members on a volunteer basis. Their power lies in the value of resources that each brings to the KOST. There are boundaries of the KOST when it comes to its content and goals including bioscience industry development. This goal naturally excludes organizations in disagreement over whether or not bioscience should be a “targeted” industry that competes with alternatives such as investing in the traditional industries of agriculture, oil and gas. By and large a KOST is inclusive within its defined scope.

Third, a strong KOST involves written strategies, work plans with clear time-lines to complete agreed-upon tasks, and clearly understood roles and responsibilities assigned to its members. A weak KOST suffers from unclear roles and responsibilities of its members. Fourth, a strong KOST does not just share information and gain consensus around goals and strategies which is more characteristic of a weak KOST, it involves improving competencies through social learning and bargaining among members as well as through implementation of tasks. These competencies range from gaining new research skills in particular fields to learning how to manage collaboration projects.

Fifth, a strong KOST consciously designs structures enabling it and its members to "learn by learning." Institutions learn by self-monitoring and engaging in "reflexive" processes that apply institutional memory and intelligence to regular evaluations of goals, tools and processes (Gertler et al., 2002) This effort helps to identify opportunities, problems and solutions to them. I elaborate further on the "learning by learning" concept in the next section. A strong KOST survives successive governments similar to a policy community. This is a very high bar and ideal-type construction. However, it is a useful way to differentiate various types of policy networks and to create a theory of change in commitment strategies. I argue that as the presence and strength of a KOST changes, so does its bioscience commitment strategy.

2.2.2.2 How Does a KOST Differ from Knowledge Cluster Mechanisms?

The rise of knowledge clusters led by industry rather than government agencies or traditional industry associations that play a lobbying role creates a third category of learning organization. The difference between a strong KOST and a knowledge cluster coordinator is that a strong KOST can aggregate interests across spatial boundaries within a region and country. While clusters of organizations, relationships and processes may exist in Montreal, a province-wide KOST is in a stronger position to pull together Montreal's, Quebec City's and Sherbrooke's resources and interests.

Cluster theory is rooted in Marshall and his examination of industrial districts and agglomeration where firms locate near each other creating advantages and disadvantages (Marshall, 1919). Porter's later influential work on competitiveness launched multiple studies of clusters (Porter, 1990, 1998).

Clusters are "geographic concentrations of interconnected companies and institutions in a particular field" (Porter, 1998, p. 78). Institutions are "… universities, standards-setting agencies, think tanks, vocational training providers, and trade associations - that provide specialized training, education, information, research, and technical support"(Porter, 1998, p. 78). This definition, however, equates formal and informal rules with organizations that differ from North's distinction separating the two. Knowledge clusters are distinctive in that they rely on cutting edge research concentrated within specific organizations like universities and public research organizations and rely on mechanisms that create and transfer knowledge derived from this research (Orsenigo, 2006).

Knowledge clusters differ from industrial clusters focusing on production in that they see knowledge as an engine of economic growth (Orsenigo, 2006). The emphasis is on knowledge production leading to technological innovation and a regional competitive advantage. For example, Newfoundland is a fledgling marine biotech cluster in the midst of mobilizing its specific knowledge base in fish genomics. The province intends to commercialize basic and applied research leading to large and more productive fish species. Quebec bioscientists engage in basic and applied research in the area of genomics and stem cells with the hopes of commercializing this knowledge in the form of new drugs and regenerative technologies.

Scholars generally agree that even though initial conditions like a significant university base that concentrates scientific knowledge, a history of entrepreneurship, research labs, and incentives are necessary and support the idea that biotechnology clusters do not locate in a particular place by chance, they are not sufficient to explain success, failure or types in between (Feldman & Braunerhjelm, 2006; Orsenigo, 2006). As Orsenigo (2006) notes, "…as much as agglomeration forces are influenced by structural initial conditions – *processes* are the essence of what clusters are made of" (p.39). In knowledge-based industries, what makes space relevant is more the nature of the relationships and mechanisms that facilitate knowledge-sharing leading to agglomerations (Orsenigo, 2006).

Cluster scholars treat institutions as geographically embedded in the field of bioscience, both affecting and affected by the behavior of organizations and their relationships. Small biotechnology firms, big pharmaceutical companies, clinical research organizations, hospitals, PROs, raw material suppliers and service providers locate in biotechnology clusters. They engage in formal relationships through contracting and informal ones via repeated interactions at industry events, networking sessions, or through meetings. Organizations within clusters also compete or collaborate depending upon the opportunity and the organizations' capabilities (Casper, 2007; Lazonick, 1993; Porter, 1990).

Finally, global R&D and production networks shape both knowledge and production clusters. Both type of networks involve a large number and variety of organizations engaged in many stages of R&D and production (Markusen, 1996; Piore & Sabel, 1984; Saxenian, 1996). No single firm has the capability to successfully work in all areas of biotechnology making strong networks crucial.

Clusters also involve learning where individuals and organizations share information, ideas about what works and what does not and incorporates these lessons into innovation activities. These efforts to develop knowledge occur "upstream" during the research phase as well as downstream during product or technology commercialization (P. Cooke & Morgan, 1998). The mechanisms that diffuse knowledge are either formal, through contracts, or informal through individual scientists collaborating on projects.

Spillovers result from innovative activities that impact actors not directly involved in the process. They can be positive or negative. When Pfizer publishes positive results of a clinical trial or promising basic research involving its obesity drug other firms not involved in the process benefit from the knowledge, which leads to further research and testing. On the other hand, competitors may scrap their efforts in the same area if Pfizer is able to secure a first mover advantage.

Not all knowledge is the same. Knowledge is generally divided into two categories: codified and tacit. While organizations in knowledge-based clusters like biotechnology rely on codified knowledge in the form of patents and publications, in a globalized world this type of knowledge is increasingly accessible by competitors even though rights to the inventions are protected (Maskell & Malmberg, 1999). Organizations' ability to produce, access and control tacit knowledge is most important (Maskell & Malmberg, 1999) to remain competitive. Tacit knowledge is found in organizations' daily routines. They enable learning and are difficult to replicate especially by competitors, giving firms an edge (Maskell & Malmberg, 1999; Teece D, 1997).

Clusters also act as magnets attracting large MNCs from around the world (Kenney & Florida, 2004). These firms tend to locate where there is a large pool of skilled labor, financing and market access. For example, in the 1990s Quebec successfully attracted global pharmaceutical firms and their R&D centers due to the considerable number and diversity of research universities, its competitive R&D tax incentives, and the province's pharmaceutical market. While local decision-makers hope that knowledge transfer either through formal mechanisms or spillovers occurs between the FDI and local firms, this is not always the case. Niosi's study of Quebec's biotechnology cluster and evidence presented in this dissertation shows that two distinct networks dividing big pharma and small, local biotech firms, existed until fairly recently.

2.2.2.3 Varying Characteristics of a KOST: Social Learning and Iterative Bargaining

Social Learning

Scholars have defined social learning differently but all involve some process of acquiring and combining new information with knowledge from past experiences. Hall elaborates that,

> learning occurs when "…individuals assimilate new information including that based on past experience, and apply it to future actions…a deliberate attempt to change the goals and techniques of policy in response to past experience and new information … Learning is indicated when policy changes as a result of this process"(P. A. Hall, 1993, p. 278)."

Furthermore, the learning process can take different forms and needs to be broken down into more specific types. These include policy settings, techniques, and goals (P. A. Hall, 1993).

In Gertler's and Wolfe's terms learning involves the "ability to acquire, absorb and diffuse relevant knowledge and information throughout the various institutions that affect the process of economic development and change" (Gertler et al., 2002, p. 1). But Lundvall and Borras (Lundvall & Borrás, 1997) link learning to capacity building. Social learning requires creating competencies and acquiring skills more than just accessing information (B. Å. Lundvall & Borrás, 1997).

I use Hall's definition that claims social learning involves not only information acquisition, assimilation and competency-building, but a concerted effort among participants to create mutual understandings about a particular industry, policy, strategy, set of techniques and goals (P. A. Hall, 1993). This conceptualization enables me to evaluate governance structures including the presence and strength of a KOST and its impact on commitment strategies.

Mechanisms and Conditions for Learning

This definition also suggests that no longer do individual firms or organizations have all the relevant knowledge necessary to sustain growth. Social learning provides an external source of competitiveness in addition to internally derived ones. The process involves organizations developing relationships among each other, sharing information, know-how and resources in order to solve problems.

Scholars have developed a typology of mechanisms to describe this learning process particularly as actors adapt to rapid technological change: learning-by-doing, learning-by-using, and learning-by-interacting (Gertler et al., 2002). But while these mechanisms deal mostly with firms as the unit of analysis, the question now is how do organizational institutions like National Research Centers or Genome Quebec and the range of bioscience organizations learn collectively to keep pace with this change? How do they help rather than impede efforts to sustain a competitive advantage?

The mechanism of *"learning-by-learning"* provides clues. This concept explores how institutions learn by self-monitoring and engaging in reflexive processes. These processes apply institutional memory and intelligence to regular evaluations of goals, tools and ways to identify opportunities, problems and solutions to them (Gertler et al., 2002; P. A. Hall, 1993; Sabel, 1993). But this process of organizing intelligence in social ways rather than on an individual basis can either lead to change or hold it back. It depends upon the ability of institutions to be reflexive and to monitor their success in adapting to changes in environment (Gertler et al., 2002).

Furthermore, to gain a competitive advantage it is no longer sufficient for organizations to simply have access to or control over knowledge assets. They can quickly become commodities since our knowledge in a variety of industries changes rapidly. The *capacity to learn*, to combine new knowledge in different ways, is now crucial to gaining a sustained competitive advantage. The capacity for social learning through the creation and expansion of a strong KOST comprised of stakeholder organizations and networks can drive this advantage (Ansell, 2000; Bennett & Howlett, 1992).

Finally, authors like Tony Porter argue that there are certain conditions that must exist prior to any organizational learning. These are the capacity for managing information flows like highly technical reports, and, institutionalized forms of open deliberation that lead to consensus around new rules and informed by the shared knowledge. Elements such as channels of cooperation, clear division of labor, improved procedures for information-sharing, minimum standards, regular rule changes and adjustments towards goals, and technological complexity all take many years to test and develop (Gertler et al., 2002).

Agents of Social Learning and "What" They Learn

The concept of a KOST builds on Hall's, Bennett and Howlett's understanding by focusing on "knowledge-oriented policy communities" as the agent of learning (Bennett & Howlett, 1992, p. 285). However, I emphasize *strategy* that necessarily precedes policy development. Strategy involves building consensus around overarching goals and objectives while tactics embody steps and methods required to achieve them. Furthermore, members of the knowledge-oriented policy community vary. In Hall's own words:

> Every state is tied to society by a network of institutionalized relations that structure the flow of information, resources and pressure between public and private sectors. They include: established networks for interest intermediation, institutional arrangements for the provision of public finance, and organizational ties to private centers of knowledge. These relations can have an equally

> significant impact on the state's capacity to implement certain policies and they deserve further scrutiny.(P. A. Hall, 1988, p. 380)

There is a clear distinction between policymakers who are the final decision-makers and the expert advisors who represent the different societal networks and who do not have the authority to make final decisions. Relationships among different levels of government and their agencies, industry organizations, scientific institutions and universities comprise knowledge-oriented strategy teams. These communities typically share a common belief system or "core beliefs" about goals but can differ in preferred collective strategy.

Finally, the question of what is learned includes three elements: Core beliefs, policy goals, and means of implementing them (P. A. Hall, 1993). While the first may be the most difficult to change, it presents the most fundamental and powerful type of learning that underpins policy change. It also involves *both* the state and society. Decision-makers who believe that channeling more R&D funding towards collaboration projects with industry will yield higher rates of technological innovation as well as more and better paying jobs will be difficult to sway in support of basic research with little short or medium-term impact on economic development goals. These beliefs underpin both policy goals and ways of implementing them. *Ideas* about what the goals should be and how they should be achieved become central to what is learned. At the most general level, government, industry and universities differ in what they learn. These learning objectives typically range from lessons learned from previous policies about what worked and what did not, new business models to take advantage of biotechnology opportunities and to minimize risk, and how to successfully patent and license new discoveries and technologies. For purposes of this dissertation, I focus more on how these various learning objectives are expressed and supported in bioscience policy, strategies and institutions. Below I outline some objectives related to each ideal-type group within the "triple helix" of technological innovation: government agencies, industry and universities.

Related government agencies like Ministries of industry, natural resources and health typically learn not only from their previous experience designing and implementing either bioscience strategies and institutions, or, strategies targeted at developing other industries, often knowledge-based like ICT. Some also engage in “lesson drawing” whereby lessons from both previous experience and those taken from other similar jurisdictions are combined to fit local needs.

However, *what* these organizations specifically learn varies. Ministries of industry typically are weak in their knowledge of the science and the industrial structure underpinning biotechnology. Ministries of natural resources often do not understand how to address industrial growth, or, politically oppose it based on their core belief that environmental concerns take priority. And Ministries of health as well as hospitals are primarily concerned with the quality and affordability of therapies and healthcare services for patients, not necessarily economic development goals. The missions and specific interests of each dictate what they learn.

In industry, large pharmaceutical firms, dedicated biotech companies, and risk finance organizations are primarily interested in commercializing new discoveries in order to capture a significant return on investment. *What* they learn is the scientific knowledge, how to develop the drug or manufacture the device, regulatory issues impacting their operations, how to commercialize their technologies, what government-funded R&D programs exist and how they operate, and how to manage the drug discovery, development and distribution process. We can even examine each industry group separately and find that *what* they learn can be defined at a more fine-grained level and differences emerge.

University scientists are primarily interested in engaging in basic and/or applied research in related bioscience disciplines like biology, chemistry, physics, engineering, and computer science. *What* they learn relates more to basic understandings of disease pathways and development of patentable discoveries beneficial to human and animal health, food security and the environment. Licensing opportunities have been promoted now for several years and are encouraged through university technology transfer offices.

In each area, the type of social learning mechanism ranges. Governments and industry associations have led in the facilitation of open-source innovation in the form of public-private partnerships. In industry, we see an increasing number of alliances between large pharmaceuticals firms and dedicated biotech companies in areas of R&D, information and resource-sharing. At universities, R&D collaboration projects with industry partners have increased, leading to potentially new licensed products and services.

But these same actors bring vested, competing interests that may prevent the learning process leading to new commitment strategies. The iterative bargaining process, therefore, plays a major role in determining these outcomes. Finally, the creation of a KOST, typically driven by enlightened individuals with experience in some or all three communities – government, industry and university – can aggregate and channel these interests toward consensus around a commitment to build and sustain a bioscience industry.

In an increasingly competitive and uncertain global economic environment, the capacity of individual economies to create new or change existing rules and norms to sustain competitiveness is critical. But learning about how to create the most effective commitment strategies is difficult for the same reasons. The process of social learning can help solve the problem. A strong KOST that engages in disruptive social learning and coordinated bargaining processes among its members can build high level, more holistic commitment strategies.

Scholars also argue that social learning as a force for policy change and therefore change in commitment strategies can generally take place within three different contexts. These include the state, society or among organizations that straddle these two. For example, some states develop industrial policy at arms-length from industry and university researchers. On the other hand, societal actors like industry associations within countries may take the lead in designing and implementing industrial strategies and policies, separate from government involvement.

The third type involves both public and private sector organizations – from governmental economic development agencies to industry associations to firms and research organizations – with specific roles who are trying to create or transform institutions to keep pace with technological change.[24] This process can take place more

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[24]For the purposes of this paper, I define institutions as formal rules and informal norms. Organizational institutions are the organizations created by institutions to implement established rules and programs. This understanding creates enough distinction between the two definitions enabling us to analyze how

frequently in highly technical industries like bioscience where large information and knowledge asymmetries exist making room for different types of industrial governance.

Barriers to Learning and How to Overcome Them

It is more difficult to determine when economies are *not* learning. Changes in overarching goals along with specific settings and techniques may occur as a result of conflicting negotiations without learning. A new government often sets its own agenda driven by a different political paradigm. I argue that even within different power arrangements and political paradigms, opposing sides may still diffuse information and knowledge and may even come to a mutual understanding quite different from previous strategies and policies.

In some cases, though, the actors may decide to forget and start from scratch rather than combine new information with existing knowledge and experiences. This forgetting may be as important as learning particularly in regions like Ontario where common values and practices relevant to an older industrial economy are not as effective in the "new" economy driven by knowledge-based industries (Gertler et al., 2002).

Scholars have elaborated several phases of the learning economy. Storper describes how to construct frameworks of action to devise effective policies and institutions that involve four steps: Strategic assessment; Baseline assessment of the economy's capacity including actors and resources in the target industry; Implementation of specific economic policies resulting from talk and technical assessments that build confidence and new roles; and, formal institution-building (Gertler et al., 2002; Storper, 1996). This last step should occur only *after* previous ones. This process describes a mix of public and private roles rather than an ideal Weberian state where each organization encompasses functionally discrete, hierarchical roles and responsibilities.

Critical to the process is talk or "communicative interaction"(Storper, 2002, p. 140). Here, not only do participants share information and preferences but they reach a mutual

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organizations engage in both learning and political processes, which ultimately influence institutional change.

understanding. But while previous research claims that this type of communication is most effective at building trust when conducted within public institutions, evidence from cases like Quebec and PEI weakens this claim (Gertler et al., 2002; Storper, 1996).

Sometimes public-private institutions are more effective. For example, publicly funded and privately managed industry associations can generate consensus around new goals despite competing economic development, industry and individual firms interests. However, an effective mix of incentives must be in place to encourage participation.

Various authors have coined social learning terms. These range from “politics as learning” and “Institutional Learning, or, Institutional Forgetting?” to “learning by monitoring” and “reflexive learning” (P. Cooke, 1997; P. Cooke & Morgan, 1998; Nielsen & Johnson, 1998; Sabel, 1993). While social learning may help explain different types of commitment strategies, it is very difficult to separate social learning from iterative bargaining and explanations of power alone. Each is embedded in each other’s processes.

Participants may reach mutual understandings but this may only be possible when sharing a similar political paradigm. Social learning may occur only after a new group reaches a dominant power position that influences how the problem is framed as well as negotiation agenda items. Therefore, a functionalist argument is not as powerful in explaining institutional change and development of commitment strategies. Rather, the idea of “collective puzzlement” and puzzling and powering through captures more accurately the reality of most political processes related to science-based industry construction (Heclo, 1974, p. 305). I examine the process of powering through by analyzing the iterative bargaining process in the next section.

An important concept in Bennett and Howlett’s (Bennett & Howlett, 1992) words and based on Hall’s idea is the “knowledge-oriented policy community.” I substitute “strategy” for “policy” and “team” for “community” in order to capture processes occurring before formal institutions are created. But how precisely does the process of social learning underpin the creation or transformation of institutions to capture new economic opportunities?[25]

I argue that social learning is a mechanism linking external ideas and institutions with existing principles and practices. The type of social learning - whether incremental (information-sharing) or disruptive (competence-building) - combined with the political process of choosing among and fighting for alternatives helps explain different types of commitment strategies. It ultimately offers implications for industrial change.

This approach towards understanding the political process runs counter to traditional conceptions that involve conflict as the central characteristic. I argue that many processes also involve social learning among participants. The process can lead to shared understandings of the problem and way forward.

2.2.2.3.1 Indicators: Disruptive or Incremental. The social learning process is disruptive when the KOST and its participants improve competencies in light of new opportunities and challenges. Competencies have improved or changed when: The KOST sustains itself over time by "learning to learn" through coordination channels, regular evaluations of goals and approaches, and when this process becomes routine; when organizations engage in collaborations; and when new firms establish themselves in line with the new KOST strategy. The disruptive nature of the process also implies that previous ways of doing things – research, business development, project management, exporting, FDI promotion – change relatively quickly. The net effect is a high commitment to developing the bioscience industry even though the process can create winners and losers. An incremental social learning process involves a weak KOST accessing, disseminating and processing information without significant changes in competencies.

Iterative Bargaining

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[25]Gertler emphasizes the importance of national institutions: "effective social learning is underpinned by a shared set of rules, expectations, norms and practices that arise from a common macro–regulatory framework. Although firms may wish to collaborate, if their individual evolution has not been shaped by a similar set of national institutions, the likelihood of success in achieving effective inter-firm learning will be considerably reduced" (Gertler et al., 2002, p. 16).

I define iterative bargaining as a process whereby two or more groups of actors engage in repeated negotiations over time, informed by their own changing goals, resources and constraints (Grosse, 2005). The bargaining situation involves policy conflicts among interdependent actors who have both conflicting and complementary interests (Quirk, 1989; Schelling, 1980). Furthermore, each actor's power is determined by his or her access to alternatives. This situation provides the opportunity for cooperation and coordination (Schelling, 1980).

I argue that iterative bargaining as a particular aspect of the overall political process is a necessary, though not sufficient, explanation for changes in commitment strategies. But coupled with social learning, the two provide us with a more robust understanding of how and why different bioscience commitment strategies exist. I avoid static analyses of cases that predominate in the literature by highlighting the iterative nature of the process.

To understand the negotiating positions of actors, I first segment them by categories: Government, industry and university. I examine the state using a two-tier model: national and subnational. This distinction is important in federalist countries where significant authority to shape industrial policy is devolved to provinces like Quebec and Ontario. But these jurisdictions still engage with federal government agencies in negotiations and consultations around institutions like patent regulation and R&D financing. Regions also engage globally with FDI and markets (Eden et al., 2005).

I divide the industry into subcategories: MNCs, small biotech firms, service providers and financial entities. For example, understanding the structure of Quebec's industry and the actors within it can help explain the nature of the negotiation process itself – what is negotiated, when, how and why. Historically Quebec's industry has been divided into two groups. One involves large, foreign-owned pharmaceutical firms and their relations with local clinical research organizations, universities and provincial government. The other includes small biotech firms and their relations with the same organizations (Niosi & Tomas, 2003).

Large pharmaceutical firms engaged in FDI activities and established a presence decades ago in the province to both manufacture and supply drugs to the provincial purchasing boards. Negotiations centered primarily on drug pricing and tax incentives.

Not until the early 2000s and then later after the financial crisis of 2008 did these firms begin to ally with local biotech start-ups through R&D project collaborations. Small biotech firms, through local associations in Montreal and Quebec City, voiced their interests for R&D tax credits and policies supporting access to skilled labor. The two distinct groups shared general interests in these areas, but diverged when it came to big pharmaceutical firms' power in dictating R&D alliance terms.

I argue that these categorizations help simplify analysis of interests, social learning and negotiating processes even though the overall negotiation process is complex involving different actors at different times. This is particularly the case in areas of finance, skill development and corporate governance rules. The approach also helps to understand how the power of actors can shift over time and in reaction to external shocks.

For example, prior to the 2008 financial crisis dedicated biotech firms were gaining leverage over big pharmaceutical companies. These smaller firms were the discoverers and innovators of new chemical entities and therapies turning them into valuable assets. After the financial crisis big pharmaceutical firms merged with, acquired or engaged in an increasing number of R&D alliances with small biotech firm to improve their own valuations.

The rising costs of conducting R&D in-house and competition for a smaller number of NCEs repositioned core biotech firms with valuable assets. These firms enjoyed a stronger bargaining position vis-à-vis pharmaceutical MNCs whose "make or buy" decision shifted towards "buy" as a result of this global shock. This shift created greater leverage for smaller biotech firms over big pharmaceutical MNCs.

2.2.2.3.2 Indicators: Fragmented or Coordinated. I employ a two-type bargaining model – fragmented or coordinated – in dimensions of finance, skill development and corporate governance. I define fragmented when only a limited number of actors engage in negotiations that affect the entire industry. This process can be intentional or unintentional.

For example, the state and its lead agency, typically a ministry of science and technology, may provide for open calls for information on topics like R&D policies and may even convene an advisory council made up of industry, science and ethics experts, but it may be politically expedient to limit actual negotiations to those organizations whose interests are more closely aligned with the state's.

Ontario's bioscience industry is fragmented despite the large number of firms and research organizations. Not only do small biotech firms engage less with large pharmaceuticals MNCs via R&D and other types of alliances, the provincial agencies and industry associations do not share common understandings of the industry's strategic direction. In fact, two industry associations have formed since the financial crisis. One reorganized from previous incarnations to represent an array of stakeholders from students to scientists to large pharmaceutical firms. The other is a new organization representing smaller and medium-sized firms. Since the financial crisis the government has decided not to engage fully with either organization until they agree on a "common voice" for industry. This means merging the two organizations.

A fragmented bargaining process may be the unintentional result of traditional divides among key groups. In New Brunswick, Canada no bioscience industry association existed until 1997. Instead, provincial government agencies and two local anchor firms, the J.D. Irving Ltd. Company and McCain Foods, led the bargaining and decision-making process in niche areas of forestry and plant science, one of the province's core capabilities. While the anchor firm is seen locally as a steward of the province's forests, smaller firms have served Irving and McCain's interests more than they have their own.[26]

A coordinated bargaining approach involves engaging diverse bioscience interest groups to effectively design strategies and institutions meeting their needs. This approach is particularly challenging within an industry like bioscience. Several factors affect the governance process: the diversity and number of actors, competing interests, whether or not what is being bargained for is clear, scientific complexity, and the financial and skill requirements necessary to manage the process all impact the capability of actors to negotiate effectively.

A coordinated bargaining approach is not without its share of conflicting interests and ideas about the way forward. But the process evolves, participants exchange information

[26] Author Interview, 23 July 2010, New Brunswick

and ideas, build knowledge and competencies, and can develop a shared understanding of both the challenge and solutions to it. The end result is consensus around choice of commitment strategy. Prince Edward Island, Canada is a representative case.

2.2.2.4 Interaction Effects

Social learning and iterative bargaining tend to interact and form part of the overall political process. Even though regular negotiations are often conflictual, they can involve evaluations of previous policies in light of new information related to science and industry trends, opportunities and challenges. Consensus can form around goals and strategies through a deliberative and flexible process. This process produces learning spillovers among KOST members and between KOST and non-KOST participants that improve competencies and the likelihood of engaging in high levels of commitment. I clarify as much as possible definitions and indicators while still capturing the nuances of such a process. Theories of conflict and negotiation alone do not explain outcomes. Social learning and iterative bargaining combined provide a more robust explanation.

2.2.2.5 Causal Mechanisms: Puzzling and Powering Through

Why does a strong KOST lead to a high/holistic commitment strategy?

A strong KOST is inclusive, flexible, deliberative and engages in disruptive social learning and coordinated bargaining processes that build competencies. It accesses the latest information and knowledge about bioscience as well as best practices through KOST learning structures. These include: members' global networks and those developed through the KOST where knowledge spillovers occur; subject matter committees tasked with conducting strengths, weaknesses, opportunities and threats analysis; regular formal interactions to design and implement work plans in line with industry goals; and regular monitoring and evaluations of progress. These structures and processes affect ways of thinking about challenges and opportunities in light of new information and occur prior to changing or creating new institutions.

This knowledge is diverse covering new ways of providing risk financing, creating training and immigration policies, and changing corporate structures in response to global shocks. Given key characteristics of a strong KOST - particularly its inclusive structure, deliberative processes over time, clear roles and responsibilities, formal strategies and work plans with timelines and agreed-upon tasks - participants are more likely to provide insights and represent interests that span critical areas of bioscience industry development. This dynamic increases the number of possible solutions to bioscience industry challenges and builds competencies. The approach is strategic and frames the challenge to include all three areas of finance, skill development and corporate governance, not just low hanging fruit like increased R&D spending or construction of a new technology incubator. This process causes a paradigm shift as core beliefs change reflecting new understandings of the opportunities and challenges.

The social learning process is disruptive as the KOST continually monitors, collects, disseminates, deliberates and acts on new information and ideas about the industry and reflects on the effectiveness of its commitment strategy. Its own competencies change, displacing old ways of thinking and approaching problems that have spillover effects among its members who also design their own organizational strategies. With this intentional approach toward accessing the latest information and ideas about the industry and how to sustain it, the process results in a holistic, high level commitment strategy. It also helps to strengthens and expand industry networks.

Why does a weak KOST lead to a mixed commitment strategy?

A weak KOST is more likely to lead to a mixed commitment strategy. A weak KOST relies more on evaluations of previous policies than on gathering best practices globally. The approach limits the number of potential solutions to capturing bioscience opportunities.

The roles and responsibilities of the KOST participants are less clear, the deliberative process is irregular, and information-sharing rather than competency-building dominates. The social learning process is incremental and the iterative bargaining process is relatively coordinated. This learning and negotiation combination yields a mixed commitment strategy.

For example, a province might increase R&D spending tied to collaborations instead of dispersing grants to single firms. This change in programs also represents a paradigm change in the way government views its and the private sector's role in sustaining industry growth. But the same region might not align skills development with industry needs or combine *both* FDI-led and local industry-led bioscience growth. This mixed approach can stem from limited access to or use of lessons learned from other jurisdictions and unclear understandings of the role of each KOST participant especially in light of a global shock like the 2008 financial crisis. As participants scramble to figure out what to do next they are more likely to rely on past settings, techniques and paradigms since the deliberative process is irregular. This process can also limit the KOST's ability to develop its own competencies.

Why does the absence of a KOST lead to low levels of commitment?

When no KOST exists learning spillovers decrease and organizations benefit less. Organizations have less access to the latest industry information and struggle to build knowledge and competencies. Even though individual firm strategies underpin the industry, no organization can solve problems and capture opportunities on its own given the high cost of doing so.

Few organizations can commit to industry growth without significant learning spillovers from participant interaction within and outside a KOST. Industry cannot generate consensus around goals and a strategy for reaching them without understanding how to proceed. The process requires regular evaluations of goals as well as creating, gathering and sharing lessons learned, technical information on markets and science, and firm experiences. It is more likely that at best only changes in settings like the level of R&D funding will occur in response to global shocks. These changes are relatively easy to implement but easy to reverse.

Other forms of policy networks can and often do exist within a single region or country. But they compete for resources as each pursues its own goals and strategies to reach them. Disruptive or incremental social learning can take place but within individual firms and policy communities as they build their own competencies. Iterative bargaining can occur within each community but not across communities through a KOST.

The two-by-two in the next section loosely captures characteristics of these dynamics. However, these categories are not hard and fast into which each case neatly fits. They are "ideal-types." Some regional cases shifted into other categories during the pre- and post-2008 global financial crisis time period. Furthermore, the pre-2008 period is generalized to capture changes in governance structures and resulting commitment levels on average since the early 1980s. I analyze this period leading up to the few years prior to the global financial crisis of 2008 for each case. This approach helps to create the context within which new commitments, if any, were made.

2.2.3 Additional Explanations

The presence and strength of a KOST does not fully explain why regions develop different commitment strategies. Varying factor endowments including natural and human resources impact the extent to which regions commit to developing their bioscience industry. Size can matter. Prince Edward Island is a small highly committed province while Ontario is a large industrialized province with signs of mixed commitment levels. Existing industries can either compete with science-based industries for resources, or, create knowledge spillovers to spur new industries like bioscience. Regions within countries help shape and implement national institutions but they do so differently. Both countries and regions within them respond differently to global shocks. Finally, path dependence helps to explain why Ontario has struggled to design holistic bioscience strategies while Quebec maintains its high level of commitment. I develop a research design that builds on some of these explanations while controlling for others to examine the impact of a KOST on commitment strategies.

2.2.3.1.1 Factor Endowments. Provinces contain a different mix of factor endowments from natural and human resources to specialized infrastructure that could lead to varying levels of commitment to bioscience. For example, decision-makers in a jurisdiction with scarce skilled labor will likely choose not to invest in a bioscience industry. We should expect resources to be diverted towards more promising alternatives. This argument builds on the traditional theory of comparative advantage as well as on how factor endowments affect the creation of institutions (Acemoglu, Johnson, & Robinson, 2005; R. E. Hall & Jones, 1999; Ricardo, 1817). I control for these factors by comparing similar "catch-up" provinces in Atlantic Canada and separately comparing the two larger industrialized provinces of Quebec and Ontario. While factor endowments do impact the choice of R&D investments in particular knowledge areas such as bioinformatics versus agricultural biotech, they do not fully explain why we see different levels of commitment to bioscience even within provinces with similar endowments.

2.2.3.1.2 Size. A jurisdiction's size can affect its level of commitment to bioscience. It may be easier for smaller jurisdictions to commit since they can more easily identify stakeholders, generate consensus given the smaller number of competing interests, and dedicate resources in support of industry goals. Larger provinces have more difficulty in facilitating high levels of commitment to bioscience for the opposite reasons. However, small size can work in the reverse direction in that vested interests may more easily hold back much needed changes to existing institutions or creation of new ones. Larger provinces with their higher numbers of industry stakeholders have access to more ideas and ways of solving problems than smaller provinces, which can lead to higher commitment levels. I control for size by comparing the small rural Atlantic Provinces separately from the large industrialized provinces of Ontario and Quebec.

2.2.3.1.3 Rival Industries. Rival industries could have negative or positive effects on the commitment toward developing knowledge-based industries. Provinces with strong traditional industries such as automotive and agriculture compete for limited public and private sector resources. Capturing these weakens support for "industries of the future" like bioscience. Those actors who designed existing institutions to help facilitate goals of traditional industries can dominate the industrial policy agenda even after a global financial crisis. Old institutions and vested interests win out over new commitments to developing knowledge-based industries potentially offering long-term benefits. On the other hand, it is reasonable to expect that successful industrialized provinces such as Ontario and its automotive and plastics industries should be able to commit highly to new growth industries like bioscience. Knowledge spillovers from traditional to science-based industries or spillovers from a province's economic governance experiences in one sector to another could occur but they often do not (Stiglitz & Greenwald, 2014). The same governance structures that worked in one industry may not in another since not all industries follow the same logic. Biotechnology and biopharmaceuticals must overcome initial market failures given high risks and uncertainties related to the drug development process.

2.2.3.1.2 National Institutions. I use national institutions like R&D funding and IPR as a control variable in order to compare Canadian provinces operating within the same country and to demonstrate the importance of provincial commitment strategies. I also include this variable to demonstrate that not all provinces design strategies that interpret or implement national institutions in the same way (Gertler et al., 2002). Nor do provinces influence the design of national institutions equally. For example, Atlantic Canadian provinces gain access to federal R&D funding through the Atlantic Canadian Opportunities Agency (ACOA). PEI is the smallest province but has secured more funding than Nova Scotia, the largest province.[27] Quebec is more strategic and has influenced national R&D funding areas like genomics and strengthened its own patent legislation using national IPR as a benchmark. Ontario has had weak strategic approaches towards influencing national bioscience institutions as part of its own commitment strategy. The presence and strength of a KOST at the provincial level helps to explain some of this variation.

2.2.3.1.3 Global Shock. I treat the 2008 financial crisis as an external shock. Finance is critical to sustaining a bioscience industry given its market failures and long product development cycles. It is reasonable to expect that the financial crisis similarly affects

[27] Author analysis of ACOA contract awards since 2006.

aspiring bioscience provinces like those in Atlantic Canada. The sudden scarcity of risk finance should equally impact the industrialized provinces of Ontario and Quebec. In theory all countries and regions within them with some level of commitment to growing a bioscience industry should be affected. While a financial crisis can cause a change in commitment from a high to low level, it does not necessarily cause change in the opposite direction from low or mixed, to high levels, or, no change. It is possible that Atlantic Canadian provinces were never part of the global financial network that includes VCs and other risk capital funding. It follows that we should not expect a change in commitment strategies in those regions. The evidence contradicts this claim. The theory does not fully explain why bioscience clusters like PEI's continue to commit and grow while others like Nova Scotia's stagnate. Furthermore, Quebec appears to be more strategic in responding to the crisis by creating new learning structures to help regain strength even though the financial crisis negatively affected both Ontario and Quebec. Ontario is still fragmented with no real strategic response.

2.2.3.1.4 Path Dependence. Theories of path dependence explain why certain provinces have difficulty changing their commitment strategy. Previous industrial policy decisions, events and related formal and informal institutions tend to resist change (Mahoney & Thelen, 2009; Thelen, 1999). This reaction is primarily due to vested interests and to the difficulty of changing social norms around acceptable ways of operating within a particular industry. Changing cognitive and organizational frames to value the long-term benefits of knowledge-based industrial development can take generations, making these investments politically unacceptable given the preference for short-term, measurable returns on investment. Path dependence offers a partial explanation as to why some provinces resist adapting institutions to new opportunities. Those provinces that established institutional complementarity in finance, skill development and corporate governance rules *prior* to an external shock like the 2008 financial crisis are more likely to withstand it even though changing existing commitment strategies may be difficult.

Path dependence theorists agree that the major cause of institutional change is an external shock. The shock creates a "critical juncture" where actors reassess interests and negotiate new institutions that help them take advantage of new opportunities that they could not on their own. This process creates a new equilibrium. However, some provinces changed their commitment strategies after the 2008 global financial crisis while others did not. The two-by-two below illustrates these different processes, governance modes and commitment strategies at the sub-national level.

Puzzling & Powering Through:

A Knowledge-Oriented Strategy Team (KOST) and its Characteristics:
Effects on Bioscience Commitment Strategies
(Pre & Post 2008 Financial Crisis)

		Social Learning	
		Disruptive	Incremental
Iterative Bargaining	Coordinated	**IV: Strong KOST** **DV: High commitment strategy** **Representative Cases:** *Pre-2008: Quebec* *Post-2008: Quebec, Prince Edward Island*	**IV: Weak KOST** **DV: Mixed commitment strategy** **Representative Cases:** *Pre-2008: Ontario, Prince Edward Island* *Post-2008: Nova Scotia*
	Fragmented	**IV: No KOST** (But multiple policy communities) **DV: Mixed commitment strategy** **Representative Cases:** *Pre-2008: Nova Scotia* *Post-2008: Ontario*	**IV: No KOST** (Few if any policy communities) **DV: Low commitment strategy** **Representative Cases:** *Pre-2008: New Brunswick, Newfoundland* *Post-2008: New Brunswick, Newfoundland*

Figure 3 The Political Process: Puzzling & Powering Through

2.3 Conclusion

This chapter presented a theoretical framework with which to understand varying bioscience industry commitment levels and changes in them among Canada's provinces. I argue that those regions with a strong KOST in place prior to the 2008 global financial crisis, or, create one in reaction to it are more likely to generate a high commitment strategy. The next chapter places Canada in global context as it attempts to develop a globally competitive “bioeconomy”. Case chapters follow while the concluding chapter highlights empirical findings, theoretical and policy implications, and future research directions.

The following chapters evaluate in detail the empirical evidence from country and regional case studies. They evaluate the roles of a KOST and policy communities combined with other explanations including natural resources, national institutions, rival industries and size for the changing nature and level of bioscience commitments.

Chapter three compares Canada with the United States and Australia, two other industrialized, federalist countries, and their responses to the 2008 global financial crisis. While these countries converged around the concept of the “bioeconomy,” they diverged when it came to designing strategies in support of it. This divergence occurs not only at the national level, but sub-nationally.

Chapter four evaluates the Quebec and Ontario cases representing large, industrialized provinces within Canada with significant bioscience assets. The chapter determines whether or not commitment levels changed and explores the role of a KOST and other variables throughout the process. It provides insights into how large, industrialized regions can either maintain high commitment levels through disruptive social learning and iterative bargaining processes after a global shock, as in the Quebec case, or mixed levels through fragmented policy communities such as in Ontario.

Chapter five analyzes the small, rural yet aspiring bioscience provinces in the Atlantic Canada region. The chapter contrasts the *least likely case* of Prince Edward Island and its strong KOST leading to a high bioscience commitment strategy against the other three provinces and their low and mixed commitment levels.

CHAPTER 3

DESIGNING THE BIOECONOMY:

SCHUMPETARIAN COMPETITION STATES?

3.1 The Role of the State in the New Bioeconomy

The role of the state in economic restructuring is fundamentally different from the past in the way that it helps transition to a knowledge-based economy. The "Schumpeterian Competition State" and its supply-side interventions that spur economic competitiveness explain this transformation. Since the 2008 financial crisis states have increasingly called for greater integration and coordination among government agencies and directly with industry. Public-private partnerships, pre-competitive collaboration projects, filling finance gaps along bioscience value chains, and addressing the skills gap by linking university research to specific industry needs are now goals. Many countries have embraced the overarching concept of the bioeconomy as an answer to global economic competitiveness.

Yet, beneath this convergence each country's bioscience strategy in response to the financial crisis reveals distinct differences in commitment. I apply theories of institutional change including diffusion, functionalism and path dependence as lenses with which to understand these differences. Each country is converging around a new equilibrium but it is far from certain that the new institutions will sustain industrial competitiveness.

The modern biotechnology industry has evolved globally but with much volatility since the late 1970s. All OECD and many developing countries created policies supporting either biotechnology's use or its application across sectors from agriculture to human health to energy and the environment. The different business models of large pharmaceutical MNCs and small biotechnology start-up firms began to converge as early as 2000. Now both are considered drug development companies.

The 2008 global financial crisis disrupted this evolution. It was widely recognized as a very different type of global shock creating new, fundamentally different challenges:

> While biotech's past financing droughts were localized and industry-specific, the present downturn crosses national boundaries and impacts industries across the economy. It is, in a word, *systemic.* (E&Y, 2009, p. 3)

The key question now is what is the role of the state in influencing new ways of organizing economic activity? In particular, how do states facilitate knowledge-based industries? Do traditional state-industry structures persist in a path-dependent manner, or, are new institutions created or changed and how? This chapter applies the concept of the "Schumpeterian Competition State" to help answer these questions (Cerny, 1990; Jessop, 1994). The Competition State differs from previous conceptions such as the Post-Fordist State in several ways.

First, the nature of state intervention has changed from demand-side to supply side structural reforms and an explicit emphasis on technological innovation. States do not just adjust to the global economy they promote and sustain an open global economy in order to capture benefits from it. Second, the state cedes power to other non-state actors such as industry in order to create flexibility and efficiencies. Third, industrial policies embrace technological innovation and are designed to support competition and markets. Fourth, states create flexible labor markets to facilitate innovation as a primary goal.

This conception necessitates more and new modes of state interventions rather than a reduction in its involvement (Cerny, 1990; Jessop, 1994). This is particularly the case in biotechnology. The industry is new and highly complex increasing the need for state agencies and industry to learn about the most effective and efficient ways of achieving common goals. But states like Canada and Australia still engage in demand-side interventions. They create markets through procurement policies for these products.

How do states know where to look for ideas regarding modes of intervening? What strategies and institutions should they create? What is the nature of the social learning and negotiation process? Who is involved? To answer these questions I first examine the industry's challenges.

Unlike traditional industries, flexibility and constant innovation characterize today's knowledge-based industries like bioscience. Firms can choose to specialize in specific areas of the global value chain rather than vertically integrate all segments. Companies can more easily secure resources globally and expand into international markets. To do so requires frequent technological and process innovation given the rapid pace of scientific discovery and increased global competition to secure market share.

Industry viewed the 2008 global financial crisis as systemic and unchanging. It articulated the challenges and trends that were shaping a new way of understanding how to sustain innovation and growth - the rise of high-quality generics, fundamental healthcare reform, personalized medicine and globalization (E&Y, 2009). These trends illustrate how industry attempts to overcome financial constraints, create value in new product development, and learn how to compete globally within changing healthcare structures and incentives.

By 2010 the question became how to "do more with less" along with pressures to "prove it or lose it" from government regulators (E&Y, 2011). Severe financial constraints and health care systems demanding proof that new therapies are more effective and less costly than alternatives force big pharmaceutical firms and small biotech companies to develop new strategies that increase R&D efficiency. These pressures force firms to focus on core "assets" like new chemical entities. Industry and government demand highly compelling scientific data indicating a strong probability of success in commercializing these therapies. Industry began to engage in product and process innovation within a very different global context:

> In this capital-constrained environment, we can no longer afford inefficiency and duplication in drug R&D. The industry needs to remove duplication, encourage pre-competitive collaboration, pool data and let researchers learn in real time. (E&Y, 2012, p. 1)

Ideas from industry about how to address this overarching challenge come from recognized leaders and industry researchers. For example, in the E&Y *Beyond Borders* 2011 global biotech report, suggestions included revamping the United States Food and Drug Administration to quicken the drug approval process, focusing on the science and unmet medical needs rather than just the regulatory process, changing small biotech firm structures and cultures to improve innovation processes, redesigning clinical trials to focus on adaptive trials and conditional approvals earlier, and small biotechnology firms either partnering early with big pharmaceutical companies or bringing niche therapies all the way through to approval on their own. Efficiency and effectiveness are now the goals yet both are difficult to reach given financial constraints and uncertainty involved in the drug development process.

This chapter situates Canada's bioscience industry within global context focusing on each country's response to the 2008 global financial crisis. It compares Canada with the United States and Australia, two other industrialized, federalist countries. I do not examine various sub-national cases. Later chapters on Ontario, Quebec and Canada's Atlantic provinces take on this task.

3.2 Research Questions and Arguments

How and under what conditions do public and private sector actors design institutions to solve the problem of expanding the bioscience industry's opportunity structure while simultaneously de-risking investments in it? This question implies a changing role for the state in industrial policies. Are countries behaving more like a "Schumpeterian Competition State," intervening in industries to enhance product, process and market innovations[28]? Are finance, skill development and corporate governance rules and norms converging or diverging?[29]

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[28] Jessop develops the concept of the Schumpeterian workfare state whose objective is the "promotion of product, process, organizational, and market innovation; the enhancement of the structural competitiveness of open economies mainly through supply-side intervention; and the subordination of social policy to the demands of labour market flexibility and structural competitiveness." (Jessop, 1994, p. 9)

[29]Benner and Lofgren see convergence of bioscience institutions generally among liberal and coordinated market economies in areas of increased R&D funding and investments in healthcare. However, their research identifies divergence in how the industry and market is regulated, supported and treats ethical boundaries. Their results contradict the VOC literature, which argues that national institutions tend to follow a path dependence process, creating lasting differences across countries, yet coherence within them. According to Benner and Lofgren, some coordinated economies like Sweden and Finland demonstrate fragmented policies and institutions while the US and Australia tend to be more coordinated in certain areas. So there is no clear dichotomy as in "liberal" vs. "coordinated" models of capitalism.(Loófgren & Benner, 2003)

I make the following arguments. First, each country's response to a global financial crisis should be understood within the context of previous economic and industrial development experiences. At different times each country made major changes to its commitment strategies in an attempt to create opportunities and manage risks associated with them. A broader policy community has developed in some cases and the state has come to play a more activist role in facilitating the production and spread of biotechnology. In this activist role institutions are converging. Actors search both internally and globally for new ways of solving the problems of mitigating risk while capturing opportunities associated with the new biotechnologies.

By 2012 institutions began to converge. Many countries accepted that technological innovation and knowledge clusters are crucial to long-term economic development. In addition, rules governing IP and R&D funding are converging in response to WTO-TRIPS negotiations and domestic pressures. The scientific community's network of researchers in specific disease areas is also globalizing. VCs are increasingly searching for co-investors globally to share ideas, contacts, business models, financing and investments.

These networks diffuse common practices in areas like drug discovery and commercialization. However, scratching the surface we find significant divergence. Each country's economic histories, paradigms and experiences in crafting commitment strategies shaped these differences.

Second, how we understand success and failure in bioscience industry development must move beyond measures like the number of blockbuster drugs produced or revenue generation. Given the long and expensive drug development period that typically takes 10-12 years costing over $1.5 billion very few countries and regions within them are successful. Yet they continue to value and promote a "bioeconomy".

I argue that we must consider various types of learning and bargaining processes leading to different commitment strategies and ways of measuring success. Much can happen during the drug discovery, development and distribution process and each milestone along the way can be a separate measure of success. Even different biotechnology application areas like bioinformatics or agricultural biotech have different product, technology and service time-lines, affecting overall time-to-market as well as costs.

Furthermore, other short and medium-term measures can include goals like creating a diverse bioscience community, a steady increase in the number of organizations, or the creation of institutions facilitating credible commitments among government, industry and university. Achieving these interim goals can help reduce uncertainty and risk. The process can improve information-sharing, enable faster discovery and development periods and spread risk among industry stakeholders. Together they could improve countries' probability of reaching long-term goals. Managing uncertainty then becomes the primary challenge underpinning commitment strategies.

Third, each country confronts a choice, albeit narrow in some cases, of strategies and governance modes. The choice set includes whether or not to invest in specific areas of R&D, like genomics or stems cells; different application areas from marine or industrial biotech to human biopharmaceuticals; or, ways in which to plug into the global R&D and production networks.

This latter option can be broken down into others. Countries face a choice between developing platform technologies used in a particular drug development phase, or, technologies applied to each phase from pre-competitive through stage three clinical trials. They can also choose to manufacture, sell and distribute drugs as a core competency.

However, the choice set is constrained by several factors. These include the availability of scientists trained in the specific subfields and application areas; managers with experience commercializing new discoveries; government agencies with enough working knowledge of the underlying science and the industry itself to be able to design strategies with a better chance of success; a diversity of risk financing sources; infrastructure; population and market size; natural resources; and location.

Evidence indicates that the state, industry and other bioscience stakeholders seek greater coordination to move to a "health outcomes-based system"(E&Y, 2011). Firms alone cannot make all the changes necessary to be both innovative and responsive to demand for more effective, less costly solutions. This "new normal" represents a change in overarching goals related to technological innovation and public policy. This change in goal has also precipitated a change in the role of the state and the broader policy community in helping to reach it.

3.3 Comparing R&D Spending

An initial comparison among Canada, the United States and Australia reveals some intriguing similarities and differences. All three countries are industrialized and federalist with devolved powers of taxation and administration of certain federal programs to regional levels. More recently the political administrations of each have embraced bioscience as a key driver of future economic competitiveness. By 2009 the term "bioeconomy" began to permeate discussions and ideas – largely generated by the OECD and member countries - regarding not only the importance of biotechnology as a tool that cuts across many application areas – from human health to industrial biotechnology to the environment – but also how to design credible strategies and institutions that sustain these industries (OECD, 2009).

Table 8 compares biomedical R&D indicators before, during and after the 2008 global financial crisis. However, the data itself does not reveal a major change in policy per Hall's definition, only a change in "settings" or levels of R&D expenditure. Later sections address whether and how countries changed their commitment strategies in all three areas of settings, techniques and overarching goals.

Only Australia increased its federal R&D spending in medical research. This increase was due primarily to public investment while industry remained relatively steady until 2010 when investment increased but flattened out at 1.4 billion during each of the remaining years. Both the United States and Canada's biomedical R&D expenditures decreased. However, when we compare R&D spending as percentage of total business expenditures and government spending in higher education and research, Australia consistently ranks lowest while Canada comes in second and the U.S., first in these areas (OECD, 2014).

Table 6 Key Biotechnology Statistics Comparing Australia, Canada and the U.S.
Biomedical R&D Expenditures (US$B) by Public Sector and Industry*

Country	2007	2008	2009	2010	2011	2012	Compound Annual Growth Rate (2007-2012)
United States	131.3	123.8	119.1	126.3	120.0	119.3	-1.9
Public	48.0	46.9	47.9	51.4	50.6	48.9	
Industry	83.3	76.9	71.2	74.9	69.4	70.4	
Canada	6.0	6.1	5.6	5.6	5.6	5.3	-2.6
Public	4.0	4.1	3.8	3.5	3.4	3.3	
Industry	2.0	2.0	1.8	2.1	2.2	2.0	
Australia	4.4	4.3	4.6	5.8	6.3	6.1	6.9
Public	3.3	3.1	3.6	4.4	4.9	4.7	
Industry	1.1	1.2	1.0	1.4	1.4	1.4	

Source: Chakma, J., B.Sc, Sun, G. H., M.D., Steinberg, J. D., PhD., Sammut, Stephen M,M.A., M.B.A., &Jagsi, Reshma,M.D., D.Phil. (2014). Asia's ascent -- global trends in biomedical R&D expenditures. The New England Journal of Medicine, 370(1), 3-6. Retrieved from http://search.proquest.com/docview/1473894767?accountid=11107
**U.S. dollars adjusted for inflation to 2012 using NIH Biomedical R&D Price Index according to mean exchange rate for U.S. dollars annually.*

Interestingly, in the United States’ public expenditures have been erratic, with the highest level of spending occurring in 2010 and reaching $51.4 billion. But by 2012 the total amount shrank back to almost 2007 levels. This significant decrease can be partially explained by political conflict regarding the federal budget resulting in sequestration of federal expenditures.

U.S. industry has invested less and less over the years, except for a noticeable increase from 2009 to 2010, at the same time that government spending significantly increased. This short time that both US public and industry investment rose, can plausibly be explained by the federal government’s announcement, informed by the OECD 2009 bioeconomy policy agenda, of a new “bioeconomy” strategy, signaling a credible commitment to bioscience as a powerful tool cross-cutting many industries and a potential source of sustained U.S. economic competitiveness globally.

This perspective is different from the 1980s. States viewed biotechnology as a promising technology that could solve immediate human health, food security and environmental issues domestically. It was not considered a source of global economic strength. However, while the U.S. government supports a more integrated bioeconomy policy framework, it has not matched it with increased financing. Individual government agencies simply reprioritized their budgets. So the commitment in terms of financial "settings" appears to come from existing organizational institutions rather than the creation of new ones.

Finally, Canada shows a relatively steady decline in public and private sector biomedical R&D expenditures. The financial crisis significantly reduced availability of risk financing especially for small biotech firms. Prime Minister Stephen Harper and his Conservative Party applied a new paradigm favoring commercialization of new products and technologies over "blue sky" discoveries. The perception is that basic research is too uncertain and risky given longer timelines and high costs.

3.4 The 2008 Global Financial Crisis: Divergence beneath Convergence?

3.4.1 Global Context – Bioscience

2008 marked the beginning of the global financial crisis. This event negatively affected both financial markets and the economy. Specifically it precipitated a decline in much needed risk capital available to biotechnology firms resulting in industry contraction.

By 2008 the bioscience industry had changed dramatically since the early 1980s. The number of dedicated biotech firms and those using biotechnology reached 3,492 in the United States (2007), 527 in Australia (2006) and 532 in Canada (2005) (OECD, 2010). The scientific community made great strides in new discoveries from rDNA techniques to mapping the human genome to progress in stem cell research. All carry potential for progress in human health, food security and the environment.

At the same time, the pharmaceutical industry was both contracting and restructuring. Large MNCs were trying to manage shrinking drug development pipelines, expiring patents protecting high-revenue-generating drugs, and declining returns on large R&D investments. Under these conditions, biotechnology firms with drugs in stage three clinical trials were particularly attractive as either acquisition targets or potential allies with these large pharmaceutical firms.

Biotechnology firms had less and less cash in reserve, fewer VCs willing to invest in stage one or even pre-competitive stages and a weak initial public offering (IPO) environment, all of which is needed to support the long R&D and drug approval process (PriceWaterhouseCoopers, 2009). By 2009, to diversify their portfolio, big pharmaceutical firms were merging and acquiring smaller biotechnology firms with specific biologic drug products, rather than new chemical entities (NCEs). This trend coupled with the Obama administration's healthcare reform, a renewed focus on the "bioeconomy" and basic research, as well as personalized medicine all was expected to support biotechnology.

In response, new modes of industry governance now revolve around greater formal and informal coordination among actors to share information, knowledge and resources in an effort to reduce uncertainty, risk and costs. These range from open-source innovation models to government and VC financing along the entire drug development value chain.

3.4.1.1 The Challenge and Strategy Choice

During this time period, a new challenge arose: How to manage increasing scientific and industrial complexity under conditions of severe cuts in financial resources. Framing the problem, learning about what financial mechanisms, skills development and business models work and what ones do not, and negotiating a credible way forward all impact a country's ability to capture opportunities while managing uncertainty and risk. In order to frame each country's response to the 2008 financial crisis, I use this problem-focused approach.

However, the problems posed during this timeframe are naturally different than those faced by each country in the 1980s when biotechnologies were beginning to be commercialized. By 2008, the industry had experienced normal business cycles of growth and decline, structural changes, new product development displacing incumbent products and their firms. But although the difficulty in securing the promise of biotechnology generally disappointed many, especially in the industry’s inability to *quickly* produce new drugs alleviating major diseases, scientific discoveries continued. Both the science and the industrial system had become more complex, slowing down the expectations of massive and fast diffusions of biotechnologies globally. New problems needed to be addressed.

Table 7 Snapshot: Comparing Country Strategies and Institutions

	Australia	**Canada**	**United States**
Strategy	Building capacity to innovate and attract FDI; No longer compete for low cost manufacturing; Link R&D to industry (OCS now within Dept. Industry); Interdisciplinary; Niche areas of R&D – agriculture, industrial, environment, stem cells	Shift from basic to commercializable research; New mechanisms to facilitate competition; Centralize Innovation (new S&T Ministry) Niche areas of R&D: human health	New from White House - Bioeconomy focus; Integrated framework; leverage existing resources across multiple application areas Broad-based approach to R&D but with attention to human health
Role of State	State-Industry Partnerships; address market failures and facilitate innovation	State-Industry Partnerships: address market failures and facilitate innovation	State-Industry Partnerships; address market failures and facilitate innovation
Finance	Government-led; start-ups list early on ASX; low diversity of risk finance	Shift to more risk finance, industry collaboration projects, less R&D funds directly to firms with weak prospects to commercialize; low diversity of finance	Diversity of finance sources, firms, research organizations;
Skill Development	Build capacity: interdisciplinary	Immigration program designed to attract skilled workers; interdisciplinary	Interdisciplinary
Corporate Governance	Small biotechs - weak knowledge of how to create a corporate structure that attracts risk finance; sees products through approval process	Small biotech focus on core assets; alliances	Large M&As, strategic alliances

The table below captures the various orders of social learning, applying Hall's taxonomy, to each country case.

Table 8 Bioscience Finance, Skill Development and Corporate Governance (Post-2008 Financial Crisis)

	Finance	**Skill Development**	**Corporate Governance**[30]
1st Order – Settings	**Biotech R&D spending (US$)**	**Tax Credits – Scientists, Technical specialists**	**Make or Buy Decision – Amount of R&D in-house**
Canada	Gov't, industry and VC spending decreased; firms increasingly seeking financing from strategic partners	Target to increase # of masters and PhD students.	R&D increasingly external for big pharma. Biotech firms focusing new funds on core products growth and less on R&D
Australia	Gov't, industry spending increased	Increase # PhDs, technicians;	R&D increasingly external for big pharma; 93% of Revenues for whole sector generated by CSL (local biotech firm)
United States	Gov't total spending decrease; but tax credits to biotech SMEs, industry increased R&D	Bio tax credit of 2009 & 2010 for small biotechs in preclinical/clinical stage.	From "year of the deal" in 2007 to little M&A change in 2013 except for increased small biotech M&As, major decrease in big pharma M&As.; R&D increasingly external through alliances.
2nd Order – Techniques	**Diversification of finance sources**	**Program Changes**	**Diversity of R&D models**
Canada	Restructuring SR&ED, new forms of financing (seed level and later stages) of BDC VC fund; Gov't creating market by procuring drugs/technologies with innovative components; NRC restructured to be more industry-facing.	Government funding R&D but with greater focus on university-industry collaboration projects; New MBA-biotechnology programs	Internal + external with different types of relationships e.g. in-licensing/out-licensing, R&D collaboration projects, patent strategies, open-source innovation, "virtual" project companies. (PWC)

[30] Corporate governance relates to how firms develop competencies to compete. One way to achieve this is to develop or acquire either internal or external resources, or both. Additional sources of privately and some further publicly held data on corporate alliance, mergers and acquisition include: SDC, MERIT-CATI (NSF), CORE and BIOSCAN/Recap. Recap indicated that in 2013 there were 2,315 publicly announced global deals. The above table includes commonly referenced statistics reported through Ernst and Young and PriceWaterhouseCoopers through their annual biotechnology reports as well as individual country reports.

Australia	New Innovation Australia institution with responsibilities to administer new government-backed VC funds – that target along the value chain - and tax incentives to attract VCs	New MBA-biotechnology programs; Change in focus from discipline-specific to interdisciplinary (molecular bio + engineering + bioinformatics etc.) degree programs	Different types of corporate structures of early stage biotech firms; lack of transparency make it difficult to raise funds on ASX or to be acquired.[31]
United States	Highly diversified vis-à-vis other countries; -NCATS (newest NIH center) established in 2011 to focus on translational research (development); -NIH shifting focus to cancer research (fierce biotech)	Industry training straight from high school; University degree programs increase in interdisciplinarity; Industry demanding individuals who can work across domains and support more than one project	Internal + external with different types of relationships e.g. in-licensing/out-licensing, R&D collaboration projects, patent strategies, open-source innovation, "virtual" project companies. (PWC)
3rd Order – Overarching Goals (Paradigm change)	**Core focus shifting (e.g. basic-commercial research, niche application areas, niche science areas, global partnerships)**	**Core focus shifting**	**Core R&D strategy shifting**
Canada	**Shift from "protect" to "compete**" – lessons learned from Australia, the US and Europe; Shift from basic research to comm.; Centralize Innovation: Re-creation of the Ministry of S&T; Biotech firms seek more "broad" R&D funding from Gov't	Shift from R&D as funding university research to university-industry collaboration projects to give researchers opportunities to develop skills needed for industry. Interdisciplinarity	Increased M&A, alliances, external R&D and VC spinouts/separate companies. Pharmaceutical firms are both vertically integrating core functions and increasing external alliances. Competences come from within and externally.
Australia	**Shift to innovation as source of long-term economic compet.** Linking R&D directly with industrial competitiveness; restructuring of existing institutions Office of Chief Scientist, CSIRO now within new Dept. of Industry (2013); sector plans developed	Interdisciplinary	Increased M&A, alliances, R&D and VC (government-backed and private) spinouts/separate companies. Competences come from within and externally.
United States	"Bioeconomy"; all-encompassing/integrative framework; individual agencies asked to prioritize biotechnology in annual budgets;	Greater Interdisciplinarity	Increased M&A, alliances as well as R&D and VC spinouts/separate companies among small biotechs.[32]

Sources: Ernst and Young and PriceWaterhouseCoopers annual reports, 2008 - 2014; Country bioscience strategy reports.

[31] See http://lifescientist.com.au

[32] Company stakeholders are demanding more oversight and diligence by boards in a variety of areas. The US Sarbanes-Oxley Act has changed the governance landscape on a global basis -new rules and regulations for accounting and disclosure, internal controls and risk management.

3.4.2 Canada: To Protect or Compete - A New Economic Order?

"We are at the dislocation point between an old economic order and a new one that may last for decades, if not centuries…Innovation is the wealth creator in this new order"
-Tom Jenkins, Chair, Innovation Canada: A Call to Action Expert Panel Report

3.4.2.1 Introduction: Response to the Challenge

By 2008, debates around the most effective R&D and innovation strategies centered on how best to translate basic research into commercializable products and technologies. This is a puzzle common to most countries. The Canadian government was comparing its disappointing innovation results with others like Germany, South Korea and the United State, concluding that a greater emphasis on downstream commercialization would help resolve its weakening position globally. This new approach represents a paradigm shift.

Between 2007 and 2013 Canada undertook five explicit strategic and institutional changes related to its bioscience industry. First, the Canadian government, elected in 2006, applied a new neoliberal economic paradigm shifting its focus from a country that "protects" its industries to one that enables them to "compete" (Jenkins, 2011a). Changing the Canadian mindset to embrace competition, entrepreneurship and innovation was the priority.

Second, the same government restructured its bioscience strategy and related institutions. It emphasized a more centralized innovation system by resurrecting its Ministry of Science and Technology, which existed in the early 1990s but quickly disappeared only four years later. The NRC is being restructured to be more industry-facing, coordinating research projects with industry and financial organization needs, while shifting away from its basic R&D and public policy mission (Jenkins, 2011a).

Third, the government and industry decreased their biotechnology R&D spending. Government restructured its financial settings and mechanisms to favor more collaboration projects between research institutes/universities and industry and less on basic research. The state would also create a market for innovative products by procuring, for example, drugs and technologies that include innovative components.

Fourth, the government is also shifting its focus in the skill development area by setting a target to increase the number of graduate students in the related sciences, adding more MBA programs that focus on biotechnology, and more funding for university-industry collaboration projects that help train scientists for industry needs.

Fifth, pharmaceutical MNCs reduced their internal R&D budgets, increased the number and diversified the nature of external relationships especially with small biotech firms. These relationships take the form of in-licensing, out-licensing, co-development, patent strategies, mergers and acquisitions, and pre-competitive open source alliances. Small biotechnology firms are investing more in their core strengths and products, less in R&D(PriceWaterhouseCoopers, 2013). And small biotech firms are experimenting with new business models including "virtual companies" where the core asset is an NCE and inputs are secured globally so that investors can control transaction costs while financing high potential product development.

The National Innovation System

Canada's federal and provincial governments are responsible for the framework conditions that support science, technology and innovation. These range from tax systems, IPR and labor mobility to competition policies, FDI and trade.[33] The country's national innovation system involves several categories of organizational institutions and their relationships. These include The National Research Council and its distributed system of centers of excellence throughout the country, several research hospitals, biopharmaceutical firms including large pharmaceutical MNCs and small biotechnology companies, government agencies including the Ministry of Industry, Minister of State for Science and Technology, Ministry for International Trade supports innovation sciences and technology globally. In finance mostly government-backed VCs, some angel investors, and the Toronto Stock Exchange, particularly its Venture Exchange, fund

[33] Canada is a federation of ten provinces and three territories. Its constitution assigns different responsibilities to federal and provincial governments. Provinces are responsible for education, natural resources and health. The federal government is in charge of national defense and foreign policy.

product commercialization and corporate growth. The government creates markets by setting prices on patented therapies via its Patented Medicine Prices Review Board (PMPRB) and procuring these drugs.

The Strategy Debate: R&D Democracy versus R&D Meritocracy

The strategy debate centered around three main tensions: equalization of R&D spending versus R&D investment in highest potential technologies; basic versus applied research; and the role of the state. The idea that all firms and university researchers should have equal access to government R&D funding stemmed from Canada's wealth redistribution institutions elaborated in its Constitution as well as in social norms attaching greater value to this understanding. These traditions historically permeated how the country approached its role in facilitating technological innovation.

But by 2008 debates about the effectiveness of these inherited principles and practices were being questioned within the context of how to improve Canada's position in the global economy. The strategy debate crystallized around how to increase return on R&D investment and whether to continue to:

> Spread cash far and wide – across all regions, industries and institutions, companies large and small – in the faint hope that something good will come of it… or…favoring the few (with highest growth potential) at the expense of the many" (McKenna, 2011, p. 1).

Up until 2012 the traditional federal mechanisms for financing R&D centered around three main programs: The Industrial Research Assistance Program (IRAP), Scientific Research and Experimental Development (SR&ED) tax credits, and the Natural Sciences and Engineering Research Council of Canada (NSERC). IRAP, managed by the National Research Council, provides financing and technology assistance to small and medium-sized enterprises engaged in innovation. SR&ED is a tax credit for small start-up investing in R&D. NSERC financially supports university-firm collaborations. The federal government also finances PROs, like Genome Quebec, and university centers, but more for basic and applied research.

However, the fundamental debate regarding federal government financing centers around whether the strategy should continue to include significant funding for basic and applied research, or, for commercialization of new discoveries and technologies. Furthermore, how to implement such a strategy remains controversial as the debate among stakeholders reveals many choices.

In 2008 and then in 2011 the choice was made.[34] The Jenkins Report laid out its logic and was clear in its recommendation to improve Canada's competiveness through innovation by dismantling the country's sector strategies. Jenkins (Jenkins, 2011b) stated:

> Competition is the fundamental motivation for innovation in a rational organization. Canadian sector [six] regimes limit competition in large, critical segments of the economy...If there is one single economic lesson about the most effective way to create wealth from the past century, it is that open market competition is the most effective and efficient basis for the economy of a nation. We would be wise to remember this lesson…We can't have it both ways. We either protect or we compete." (p.1)

In addition, the new strategy emphasized how to balance government "support" with intense competition to increase innovation levels. Support would be targeted in areas like government funding of R&D, more masters and PhD students, skilled investors, capable managers and bigger markets with better supply chains through international trade. Competition would come from investor demand for profitable growth and from intense competitors globally. The strategy assumes that both processes would positively impact innovation in Canada.

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[34] Under Canada's "Mobilizing Science and Technology to Canada's Advantage" 2008 strategy the country developed four strategic priorities: environmental science and tech; natural resources and energy; health and life sciences; and ICT. The Science, Technology and Innovation Council identified sub-priority areas for R&D in Life sciences: regenerative medicine, neuroscience, health in an aging population, biomedical engineering and medical technology (Fast, 2007).

This paradigm represents a fundamental shift from previous industrial policies that did not explicitly make this linkage. And while biotechnology was not a traditionally protected industry, the 2011 panel suggested that Canada refocus its resources on the commercialization phase of discoveries and inventions (Jenkins, 2011a). By 2012, the federal government outlined its new innovation strategy.

It rapidly adopted many of the recommendations, emphasizing mostly structural changes and reallocation of funds from basic to applied research and commercialization. The SR&ED program was reworked and offered only labor-based tax credits, not other types. Savings from the SR&ED would be reinvested into direct support for business innovation programs like the IRAP. Primarily industry-university R&D partnerships would become eligible for funding, less on basic research. It also sought to increase the Business Development Bank of Canada (BDC) VC funds in order to provide additional financing to firms at both the seed level and later stages.

These fundamental institutional changes were controversial. For example, Canada's largest trade and industry association, Canadian Manufacturers and Exporters (Lothian, 2011) claimed that the expert panel failed to take a comprehensive look at all federal R&D programs, and singled out one, the SR&ED tax credit for start-ups, which restricts eligibility and reduces funding (CMC, 2011; Lothian, 2011). The CME believed that this program was critical for small firms still in the start-up phase and for FDI making decisions about R&D investments in Canada (CMC, 2011; Lothian, 2011). Universities also criticized the lack of understanding by the panel and largely the federal government now in power of the value of basic research especially as the basis for invention and innovation. Finally, the CME claimed that the federal government ignores the bigger issue of how to improve funding models for university and government research as other countries have.

BIOTECanada, the country's bioscience industry association generally supports the federal government's new strategy to promote private sector innovation. However, industry prefers the new policies to address the eight specific bioscience sectors, specifically through a centralized planning between government and industry that supports a common strategy (Brenders, 2011). Industry agrees that the federal government should take on this lead role but that coordinating with provinces is *essential* especially in areas where the provinces invest significant amounts of funding such as healthcare. In 2014 both levels of government are renegotiating the federal-provincial agreement on the transfer of payments for healthcare. The CME argues that this renewal offers an opportunity to identify common objectives and establish mechanisms to adopt innovative processes for the healthcare sector (Plecash, 2012).

3.4.2.2 Finance

The Canadian government significantly decreased investment in biotechnology R&D while industry levels remain relatively unchanged from 2007 to 2012. By 2013, industry decreased R&D spending by 13% and VC funding declined to their lowest point in 10 years (E&Y, 2014). As the number of firms decreased, government and those firms that remained began fundamentally restructuring and diversifying institutions and mechanisms to reduce transaction costs, leverage resources and focus on commercialization of new products and technologies. While the number of mergers and acquisitions was steady, the number of reported strategic alliances declined significantly. However this is likely the result of fewer existing firms.

The federal government provided the context for change by bringing with it a new paradigm for the country's R&D strategy. A strategy shift from "protect" to "compete" also impacted the nature of new institutions. We see that the ideas for these new institutions like the creation of a Competition Agency separating enforcement from advocacy comes from researching and comparing existing institutions in Australia, the US and Europe and is also a reaction against existing Canadian rules that do not separate the two functions.

Industry reacted to the sudden decrease in global risk finance for biotechnology R&D by increasing the number of mergers and acquisitions to secure new patents and related technologies. While the number of reported strategic alliances has decreased, the nature of these relationships is increasingly financial. Finally, industry increasingly encouraged government to make R&D financing more broad-based versus specific to functional or disease areas at the exclusion of others. All of these activities took place as government and industry actors were collectively trying to figure out how to remain competitive in such a severely constrained financial environment.

3.4.2.3 Skill Development

Despite a globally competitive university research base, the skills gap still exists in certain areas of bioscience and industry. These include: interdisciplinary science/engineering programs with a greater emphasis on commercialization; professional services in regulatory and commercialization processes; and government program managers with weak science or industry backgrounds. The role of the state and industry in building this capacity is changing as the challenge of commercializing new discoveries becomes even more urgent.

Ensuring that relevant government agencies involved in bioscience strategy and policy development and implementation possess the requisite scientific and industry knowledge is difficult. For example, the private sector has indicated that staff administering the SR&ED tax credits are not necessarily qualified to conduct the due diligence necessary to ensure that applicants qualify for such financing (CMC, 2011; Lothian, 2011). The private sector also believes that BDC operates like a traditional bank. Staff is not necessarily trained in specific sciences and industries like bioscience, but rather generally through MBA programs which means they are not capable of evaluating the science behind the investment opportunity. The understanding is that scientists need to become better managers while managers need to better understand the underlying science behind firm’s products and processes.

3.4.2.4 Corporate Governance

Small biotechnology firms that could not survive the financial crisis closed down while others began changing their business model to focus on fewer NCEs and niche areas. In some cases, the corporate structure changed towards a “virtual” model to focus on the NCE, or asset, itself while importing human and financial resources from global sources. This approach has not yet been proven successful, but the motivation behind the change is to reduce overhead costs, build in flexibility to the corporate structure, ensure access to the most capable human resources, whether local or global.

Large pharmaceutical firms closed their R&D facilities, in some cases reconfiguring them into investment organizations, and began allying with small biotechnology firms and government PROs. VCs began investing in shorter time-spans along the drug development value chain to capture highest revenue opportunities; and, national institutions reconfigured towards commercialization efforts.

3.4.2.5 Conclusion

All of these changes reflect state-level and organization-level social learning. Canada was reacting to previous strategies and policies that, while successful in generating new discoveries through basic research, were less so in commercializing them. Simultaneously, government and industry searched externally for new ideas and ways of intervening to facilitate biotechnology growth.

The state and industry's goals were more aligned during this period and to a certain extent represent a consolidation of trends that began prior to 2008. On the other hand, the sudden and severe contraction in risk finance, especially important for such a highly uncertain and risky industry like biotechnology, has forced even greater policy innovation. The universities are shifting towards more collaboration with industry, some reluctantly as basic research is garnering less attention.

The Schumpeterian Competition State concept captures the major shift in Canada's approach towards growing knowledge-based industries. There are more mechanisms linking government and industry with a clear goal to facilitate commercialization of products and technologies, train scientists, engineers and managers in these processes, and incentivize firms to create new competencies and governance modes in order to compete globally. Furthermore, Canadian biotechnology firms are asking for stronger partnership with government especially in the latter's ability to provide access to risk finance.

3.4.3 Australia: Building a "Modern" Economy

"…We must be an anticipator nation and not a follower—a nation which gives as it receives; a nation engaged in a two way flow of know-how through which we learn as we contribute to the solutions we will all desperately need."

– The office of the Chief Scientist

3.4.3.1 Introduction: Response to the Challenge

Australia's response to the 2008 financial crisis was explicit. It involved accessing ideas from external sources such as the OECD and the concept of the "bioeconomy" and reacting to previous bioscience policies stemming from its first strategy developed between 2000 and 2008 (AusBiotech, 2014a). New strategies were designed and a high rate of institutional change and creation, greater focus on knowledge-based industries including cutting edge biotechnology, and stronger interaction between the state and industry characterizes this period.

However, while prioritizing Australia's economic position globally, the Australian government's strategy and institutional changes involve a more all-encompassing, integrative framework - basic and commercializable research, educating the public, negotiating with unions - compared with Canada's which is clearly focused on industry collaboration projects and investing in the most promising technologies. The challenge for Australia is to shift from a more generic approach towards its interactions with industry and university to learning more about the specifics of biotechnology, what works, what does not in terms of how to effectively facilitate industry growth.

Again, the challenge facing all industrialized countries during this time was how to manage increasing scientific and industrial complexity, uncertainty and risk while creating opportunities with scarce financial resources for R&D. By 2013, while Australian biotech firms' revenues and income increased, they were spending less on R&D (E&Y, 2014). However, Canada's situation was worse, biotech firms were also spending less on R&D and generating lower revenues (E&Y, 2014). We see some convergence of financial institutions when comparing with Canada, yet divergence in niche areas of R&D, skill development policies and corporate governance.

3.4.3.2 The Innovation System

Australia's industrial biotechnology structure by this time included a large local anchor company, CSL, which accounted for 93% of the industry's revenue by 2013 (E&Y, 2014). The remaining 7% of revenues is generated by 470 small firms, 130 of which are core biotech, as well as foreign subsidiaries of big pharmaceutical firms. Some are profitable, selling products in areas of health, industrial processing, agriculture and the environment. Australian states have also designed their own strategies focusing on different R&D areas including tropical medicine, bio-discovery, regenerative medicine, bioremediation, agricultural/industrial biotech and medical devices.

Most R&D in Australia takes place in both universities and hospitals and jointly with industry, particularly large MNCs with subsidiaries in Australia. In contrast to Canada's recent restructuring of its national health research agency, the NRC to be more industry-facing, Australia's national health research institute, the National Health and Medical Research Council's (NHMRC) core mission remains focused on supporting health and medical research and advice.[35] It is the Commonwealth Scientific and Industrial Research Organization (CSIRO), with a budget of $1.6 billion in 2012/2013 that seeks to generate "innovative scientific and technology solutions to national challenges and opportunities to benefit industry, the environment and the community, through scientific research and capability development, services and advice".[36] However, in 2014 CSIRO signaled a change in goals more narrowly focused on supporting commercialization of R&D globally. It appointed Dr. Larry Marshal as its new Executive Director who is a scientist and entrepreneur with global experience managing both VC and start-up biotechnology firms. CSIRO emphasized the social learning role it plays in ensuring "that it continues to

[35] See http://www.nhmrc.gov.au/.
[36] See www.csiro.au

provide advice of the highest quality to Government as well as provide best practice collaboration with the private sector" (AusBiotech, 2014c).

3.4.3.3 The Strategy Debate

In 2009 the Australian federal government produced a new strategy, "Powering Ideas - An innovation agenda for the 21st century," along with a Strategic Roadmap for Australian Research following the country's first biotechnology strategy that spanned 2000-2008. The timing of strategy indicates that the country was also reacting to the global financial and economic crisis forcing them to search for new ways of remaining globally competitive. The approach explicitly included biotechnology as one of four key technologies. Decision-makers claimed that Australia was one of only six countries capable of benefiting from 16 future applications arising from biotechnology, nanotechnology, materials science and information technology. The other five were Canada, Germany, Israel, Japan, Korea and the United States.

The Minister for Innovation at the time, Kim Carr, clearly indicated that the new strategy was in direct response to the global financial and economic crisis:

> Investing in innovation is also one of the most effective ways we can cushion Australia against the effects of the global downturn and accelerate recovery. It will simultaneously keep people in work today and generate jobs for the future. (Australia, 2009d, p. 1)

In addition, he clearly linked Australia's long-term economic competitiveness prospects with new strategies and institutions that build capacity and support for knowledge-based industries indicating that:

> Tough times demand creative solutions. "Powering Ideas" will help us find those solutions. It will help us transform challenges into opportunities, risks into rewards … This is a ten-year reform agenda to make Australia more productive and more competitive. Increasing our capacity to create new knowledge and find

new ways of doing business is the key to building a modern economy based on advanced skills and technologies. It is the key to success in this, the global century. (Australia, 2009d, p. 1)

By 2014, the Office of the Chief Scientist, after consultations with industry and interactions with OECD policy researchers, developed a new Science, Technology, Engineering and Math (STEM) strategy to build Australia's competitiveness, maximize research, improve education and internationalize science and technology efforts (AusBiotech, 2014b).

The new approach recognized that Australia needed to create credible commitments in support of technological innovation. Government increased its science and technology investment by 25% to $8.58 billion from 2009 to 2010 and required annual assessments over the next 10 years (Carr, 2009). Part of this package included the Super Science Initiative (Australia, 2009b).

This initiative addressed priorities identified in the 2008 Strategic Roadmap and allocated A$1.1 billion over five years to priority areas of Australian research: Space science and astronomy, marine and climate science, and future industries including biotechnology, nanotechnology and ICT. Biotechnology received A$500 million over this period. As part of the "future industries" component of the Super Science Initiative, the government in 2012 developed the more formal National Enabling Technologies Strategy, targeting "cutting edge" biotechnology (Australia, 2012).

The local biotechnology industry was negatively affected by the 2008 global financial crisis. Firms typically pursue a business model based on regularly raising capital from external sources to pursue their drug development activities. In the case of Australia, in contrast to Canada and the United States, small firms typically seek early stage financing from the Australian Stock Exchange (ASX) (E&Y, 2008). The collapse of global financial markets has weakened firms' ability to raise funds, increasing their investment risk to lenders and making it harder to support ongoing R&D activities. From 1 January to 25 November 2008, the market capitalization of listed biotechnology companies (excluding the country's only large local firm, CSL), fell by 56.7% from $4.9 billion to

$2.1 billion. But part of this weakened valuation comes from investor’s lack of understanding of the biotechnology industry (E&Y, 2008).

Despite the fall in private sector risk capital, by 2014, the Australian biotechnology industry reached 470 companies, including 130 core biotech firms and start-ups as well as profitable firms selling products in areas of health, industrial processing, agriculture and the environment (Australia, 2014). While other factors certainly impacted the industry’s growth, we see a high correlation between this growth and government’s new industrial strategy and resources supporting it. Meanwhile, Canadian and United States governments were steadily decreasing biotechnology R&D spending despite embracing ideas diffused by the OECD about the promise of the new bioeconomy.

To implement the new economic strategy, government created new organizational institutions. For example, in September 2013, the federal government created the Department of Industry and placed the Office of the Chief Scientist and other science agencies like the CSIRO, Australia’s national science agency and the Australian Institute for Marine Science (AIMS) within it. Despite other agencies with portfolios covering education, health, environment and agriculture, the Department of Industry encompasses several similar areas including industry, energy, resources, science, skills and business all to drive economic growth, productivity and competitiveness.

This move clearly indicates Australia’s strategy to link R&D to economic competitiveness goals. However, it may diminish the role of science by subordinating scientific agencies to industry. In addition, other goals including affordable healthcare, preserving the environment and basic research pursued by other agencies are perceived to receive lower priority.

3.4.3.4 Finance

Other institutional innovations were taking place increasingly in response to the financial crisis. The federal government created Innovation Australia in September 2007, an independent statutory organization designed to administer the Australian Government's innovation and venture capital programs. These include R&D tax incentives and a range of venture capital funds targeting different stages of product development. The new organization is an amalgamation of the former Industry Research and Development (IR&D) Board and the Venture Capital Registration (VCR) Board (formerly known as the Pooled Development Funds Registration Board). Innovation Australia assumed the roles, responsibilities and powers of the two former Boards. Finally, the organization is managed by a Board comprised of government, private sector and university representatives with expertise in areas of technological innovation (Australia, 2007).

One of CSIRO's four programs is the National Research Flagships designed to address complex challenges through information, knowledge and scientific solutions to increase economic, social and environmental wellbeing. The program identified several national challenges including water, food, health, energy, climate change, mining, and manufacturing representing over 40% of Australia's GDP. Given the complexity of the challenge, we see that the federal government, rather than taking an arms-length approach, advocated greater collaboration through partnerships with universities, PROs, the private sector and international organizations. Furthermore, the government advocated "continued interaction and engagement with these bodies is crucial to ongoing success and delivery and adoption of research outputs to maximize benefits for Australia" (CSIRO, 2012, p. 297).

As part of the social learning process, the Flagship program is guided by a governance system that identifies new opportunities while scaling down others. For example, while focus remains on nine flagships from Food Futures and Preventative Health to Future Manufacturing, in 2011 the Light Metals Flagship was terminated after a review process, with key activities either wound down or moved to other programs. By 2012, two potential new Flagships were being developed in the areas of Biosecurity and Productivity. Each Flagship operates within an approved business plan that guides the path to impact (Australia, 2007).

Industry was also taking steps to build strength especially by integrating and focusing existing institutions. By 2006, just prior to the financial crisis, industry established the Pharmaceuticals Industry Council (PIC), the main industry association representing the innovative, generic and biotechnology industries to provide a "whole-of-sector approach" to addressing opportunities and threats to investment in the sector. The new association integrated three previous associations – AusBiotech, Medicines Australia and the GMiA (Generic Medicines Industry Association) (AusBiotech, 2014a; Australia, 2009b, 2009c).

AusBiotech provides expertise as industry advocates and committee members on all biotech steering committees participates in policy review panels at both government and corporate levels. These mechanisms facilitate learning, but also a way to influence policy agendas and institutions.

In certain areas of bioscience, like pharmaceutical manufacturing, Australia retains some of its traditional mechanisms that coordinate interests among government, industry and unions, while establishing new ones. In traditional manufacturing industries, which in the past had high functioning unions, all three interest groups would negotiate wage rates and other interests. Beginning in the late 2000s, interests began to be coordinated around increasing investments in pharmaceutical R&D, clinical trials and manufacturing. To do so, the Minister for Innovation, Industry, Science and Research, Kim Carr, created a high level industry-union taskforce, the Pharmaceuticals Industry Strategy Group, which developed a 10-year plan.[37]

Based on the above analysis, we see the state taking the lead in framing the challenges, bringing together disparate interests, facilitating deliberation and sharing of knowledge among groups and creating consensus around strategy goals and tactics. The state is building on previous principles and practices, rather than completely throwing them away, and adjusting them towards new goals within the Schumpeterian competition state framework. Here, the state explicitly links its strategies with improving productivity, driven by technological innovation, via stronger state-industry ties. This is a key difference when compared to the country's history of organizing its economy first through protective measures then through a major paradigm shift embracing a free trade, open market system.

3.4.3.4 Skill Development

[37] Pharmaceutical manufacturing has traditionally been strong in Australia. Between 1998 – 2007. Business Expenditure on R&D (BERD) for the pharmaceuticals industry reached $860 million, accounting for 7.5% of total BERD across all industries and its R&D intensity is four times that of Australian manufacturing in general.

To learn about, understand and capture the benefits of the complexity of the science underpinning the industry, Australia recently recognized the need to change its focus from discipline-specific to interdisciplinary approaches. For example, combining molecular biology, engineering and bioinformatics concepts and methods to solve specific problems is now more widely viewed as an answer to scientific and innovation challenges. However, there are few clear examples of this approach.

3.4.3.5 Corporate Governance

During this period, Australian biotechnology firms were raising less capital but at the same time generating deeper drug pipelines, which made them attractive take-over targets. Pharmaceutical and medical device manufacturers as well as CROs were struggling to find their competitive advantage in the face of rising competition from Asia.

Small biotechnology firms along with big pharma, VCs and PROs all began to reconfigure their relationships and restructure their organizations. Companies like Pfizer Australia, AstraZeneca Australia, BoehringerIngelheim all began operations in Australia decades ago. First, they established sales offices to sell therapies and medical devices to Australia's Pharmaceutical Benefits Scheme (PBS), the government-created pharmaceuticals market. Then, MNCs began to expand and diversify by purchasing local farms supplying critical raw materials, increasing the number of manufacturing operations and investing more and more in R&D eventually in collaboration with PROs. For example, AstraZeneca Australia now spends about $250 million in R&D in Australia mostly in human health.[38] Pfizer is developing new business models that help the firm effectively engage with local research and biotechnology communities as well as the global pharmaceutical industry.[39]

However, the global pharmaceuticals business model was changing in response to falling revenues from patent expirations, rising drug costs, competition from generics and the emergence of biologics (larger, more complicated molecules offering promising

[38] See: http://www.astrazeneca.com.au/home/
[39] See: http://www.pfizer.com.au/research-and-development

therapeutics). Firms began to merge with or acquire each other and outsource early stage R&D in order to manage costs. In response, the Industry Strategy Group acknowledged that:

> Australia will only remain competitive as a destination for manufacturing exports (in pharmaceuticals) if it is able to leverage its knowledge base to undertake the high value added activity that other locations find difficult to replicate. Competing on cost is not a viable or desirable option. (Australia, 2009a, p. 34)

The real risk lies in Phase II and III clinical research. Because most industry R&D is spent by MNCs in these areas, Australia is vulnerable to global competition. These segments of the value chain are the most cost sensitive. Because the R&D at these points relies less on early researchers and the quality of R&D is increasing in emerging markets, MNCs can secure the large patient populations and lower cost base in other countries. So even maintaining the existing workforce in Australia is in question.

Small Australian biotechnology start-ups are also experimenting with new corporate structures and business models. These firms are forming alliances among each other and increasingly with big, overseas pharmaceutical firms (Herpin, Karuso, & Foley, 2005). However, the challenge is in the weak skill level of managers in these small firms to engage in complex multi-actor projects. In addition, creating a clear recognizable corporate structure – with a CEO in charge of strategy and separate Board to ensure that transparency and fairness to all stakeholders is enforced – is often not a priority. This weakness makes some small biotech firms less attractive to VCs even if the firm is able to secure funding by listing on the ASX (Trudinger, 2005).

3.4.3.6 Conclusion

The Australian case supports the Competition State theory and the state's role in influencing technological innovation. Closer, more explicit state-industry relations are intended to produce future policies and institutions designed to create a more predictable and business-friendly environment for the industry (Australia, 2010).

Again, the strategy fits with Australia's, Canada's and the United's thinking that investing in knowledge-based industries will create competitive advantages globally. Australia has a comparative advantage in agriculture and mining and to remain competitive it can use biotechnologies in these sectors. While Australia does not have a comparative advantage in pharma, health and environmental industries, biotech could help improve the country's competitive advantage in these areas. Like Canada, Australia is weak in firms with financial depth, commercialization and management expertise. Also similar to Canada, most intellectual property is licensed to overseas firms leaving both countries with the challenge of appropriating value from their investments for both commercial and economic development benefits.

3.4.4 United States: Toward a Coordinated and Integrated Bioeconomy

"The world is shifting to an innovation economy
and nobody does innovation better than America"
—President Obama, December 6, 2011

3.4.4.1 Introduction: Response to the Challenge

In response to the 2008 financial crisis, the United States developed its first more explicit and comprehensive bioscience policy that includes a range of goals related to regulatory strengthening, finance, capacity building in areas of skill development, partnerships with industry, and greater coordination and integration of resources and governance models. This 2012 strategy, the *National Bioeconomy Blueprint*, differs considerably from the country's policies beginning in 1986. These focused on creating an "economic ecology," not a direct interventionist approach of regulations like patent legislation, safety requirements, and rules governing R&D finance eventually leading to a knowledge regime encouraging commercialization (Giesecke, 2000; Vallas, Kleinman, & Biscotti, 2011).

Like Canada and Australia, the new strategy, I argue, acknowledges the United States' concern about its long-term global economic position. It also clearly incorporates ideas – advocated by international organizations such as the OECD and WTO - about the role of technological and institutional innovation as platforms for this growth (OECD, 2009). And the government, particularly the White House, appears to be taking the lead in developing this strategy.

The United States' government role in facilitating these goals is transforming through more public-private partnerships and pre-competitive consortia with industry. These mechanisms allow for social learning among the participants about commercialization prospects for new discoveries, effective financing mechanisms and regulatory requirements. But the potential for higher transaction costs may prevent such close collaboration and coordination especially if individual firms can eventually pursue similar opportunities on their own. I argue that balancing the two models depending upon the level of uncertainty, risk and opportunities will be necessary.

3.4.4.2 The National Innovation System and the "Bioeconomy"

Unlike Australia and Canada, the United States' national innovation system involves a high density, diversity and level of sophistication of bioscience organizations in terms of their industry, regulatory and financial knowledge. But while the number of firms and amount of revenue increased from 2007 to 2013, both public and private sector R&D spending along with the number of employees decreased. These changes were driven by firms leveraging resources through mergers, acquisitions and alliances to reduce costs and target niche, highly promising therapies. While Australia and Canada both have highly developed, globally competitive educational systems and scientific infrastructure, one of their weaknesses is in the lack of understanding and experience on the part of investors and managers of both the industry and specifically how to value and bring products to market.

In the United States, the role of the state changed during this process from a regulatory one, and one that clearly demarcated itself from the market, to a state that embeds itself more with industry, embracing technological innovation as a driver of global economic competitiveness. This approach differs somewhat from Cooke's conception of “relational embeddedness” in that the federal government is guiding this integration” (P. Cooke, 2004).

Furthermore, the United States was the only country in the world with free prescription drug pricing. As a result, it has steadily expanded to represent over 50% of global sales (Benner & Löfgren, 2007). This combined with its relatively high (though decreasing) R&D spending makes it the global leader in research, drug development and distribution.

In the “Bioeconomy Blueprint,” we find an explicit, broad strategy incorporating both economic growth goals as well as social and security goals. But while it was produced, with input from various government agencies and stakeholders as well as by the White House, the strategy is driven by existing government agencies. However, one new organizational institution was created to help implement the strategy, the National Center for Advancing Translational Sciences, a new Center at the National Institutes of Health, established in December 2011 so “that new treatments and cures for disease can be delivered to patients faster” (NIH, 2011, p. 1). While these changes demonstrate a heightened awareness of the need for more mechanisms that translate research into technologies and products and the broad based potential to the bioeconomy, government did not significantly increase budgets.

3.4.4.3 The Strategy Debate

Rather than a narrow focus on specific areas of basic, applied and translational research, the term “bioeconomy” now defines the emerging biotechnology industry of the 1980s more broadly. It includes many areas of R&D and their applications to a range of industries. Furthermore, the term refers to a more coordinated and integrated approach both upstream, for example in areas of stem cell research, and downstream in terms of applied R&D, technological innovation and industrial growth.

The federal government characterizes the bioeconomy and its potential benefits in the following way:

> Economic activity that is fueled by research and innovation in the biological sciences, the “bioeconomy,” is a large and rapidly growing segment of the world economy that provides substantial public benefit. The bioeconomy has emerged as an Obama Administration priority because of its tremendous potential for growth as well as the many other societal benefits it offers. It can allow Americans to live longer, healthier lives, reduce our dependence on oil, address key environmental challenges, transform manufacturing processes, and increase the productivity and scope of the agricultural sector while growing new jobs and industries. (House, 2012, p. 1)

With this understanding, the federal government asked each relevant agency to “prioritize” the bioeconomy in their budget requests (House, 2012).The National Bioeconomy Blueprint was modeled after the Administration’s 2011 Blueprint for a Secure Energy Future. It has two main objectives. First, it is designed to help realize the full potential of the U.S. bioeconomy. Second, the policy will highlight early achievements toward those objectives (House, 2012).

It is important to note that the political environment at the time was highly contentious. President Obama was elected in 2008, reelected in 2012 and subsequently passed healthcare legislation that fundamentally changed Americans’ access to and costs of healthcare. While this dissertation does not delve deeply into the healthcare legislation, understanding the political context helps to explain the more comprehensive approach the government is taking to develop a bioeconomy that is more expansive and inclusive while leveraging existing resources.

To manage the increasing scientific and industrial complexity, uncertainty and risk while creating opportunities, the United States is creating a more explicit industrial policy calling for closer state-industry-university collaboration in key bottleneck areas. These include how to ensure continuous financing from diverse sources over the product cycle, fill the skills gap and commercialize new technologies getting them to market faster, and manage uncertainty and risk.

Leading interest groups produced a series of technical reports, statements and recommendations in 2009, which informed the new strategy. For example, the National

Research Council recognized the need to reassess the science and its multiple applications to health, food, and the environment in its report, "A New Biology for the 21st Century" (NRC, 2009). The agency's findings influenced the White House's new strategy, "National Bioeconomy Blueprint," citing bioscience and its potential for improving human health, security and productivity. It stressed that:

> Biological research (offers) the potential to improve health outcomes for all Americans, feed growing populations, with higher-yield crops of improved nutritional value, and decrease American dependence on petroleum-based products while increasing domestic biomanufacturing of fuels and chemicals…the United States should capitalize on recent technological and scientific advances that have allowed biologists to integrate biological research findings, collect and interpret vastly increased amounts of data, and predict the behavior of complex biological systems. (House, 2012, p. 7).

Both the NRC study and White House strategy emphasized the benefit of coordinated federal efforts to integrate biology with other sciences like physics, chemistry, and computer sciences along with math and engineering to address a range of social challenges in health, energy, environment, and agriculture (House, 2012; NRC, 2009). Following this report, two years later in June 2011, BIO, the U.S. Biotechnology industry association, came up with its own recommendations for federal policy reform. These steps included: greater investment in innovation, restructuring of FDA and support for human health and agricultural applications (BIO, 2011).

The resulting "National Bioeconomy Blueprint" targets five strategic objectives for a bioeconomy with the potential to generate economic growth and address societal needs: Increase investment in R&D; quicken commercialization of discoveries through translational and regulatory sciences; develop regulations to reduce barriers, increase the speed and predictability of regulatory processes, and reduce costs while protecting human and environmental health; enhance training programs and align incentives at universities to meet industry workforce needs; identify and support public-private partnerships and precompetitive collaborations (BIO, 2011).

To reach each of these objectives, the federal government emphasizes coordination, integration of approaches and improved mechanisms for finance, skill development and governance. Since budget growth is constrained, leveraging and coordinating approaches can help to address common challenges and generate novel approaches through information-sharing and consensus-building around a core focus. The strategy also emphasizes that funding mechanisms should be created or changed to support creative, high risk/high reward research. Furthermore, agencies should share lessons learned and explore the possibility of creating mechanism that cut across agencies.

To improve commercialization, the strategy seeks to accelerate the cradle-to-market process, enhance entrepreneurship at universities, and use federal procurement authority to create markets. To fill the skills gap, the government is supporting employer-educator partnerships and incentivizing universities to reengineer training programs. Lastly, government indicates that federal agencies should provide incentives for public-private partnerships and precompetitive collaborations to benefit the bioeconomy *broadly.*

The above description provides evidence of social learning around how to facilitate a bioeconomy given the changes in settings like decreased R&D, new techniques such as reengineering of training programs and changes in overarching goals towards catalyzing a more broad-based, inclusive bioeconomy designed to reduce the income gap across industries. The governance mechanisms have changed as well from a decentralized system of individual agency missions and goals to a more crosscutting, integrated and coordinated approach.

3.4.4.4 Finance

The United States is the industry leader in terms of number, diversity and sheer size of the financial industry supporting biotechnology. Compared to Canada and Australia, while these countries have stock exchanges on which starts-ups list, some VCs, angel investor groups and banks managing VC funds, they do not come close to the breadth and depth of the United States. Australian and Canadian biotech firms and government specialists have cited this diversity as a weakness in their countries.

While both government and industry R&D spending decreased between 2007 and 2012, by 2013 industry spending increased by 20% as investors responded to increased revenue generated through sales of new drugs. The stock market also responded positively by increasing the market capitalization of publically traded biotechnology firms. However, in 2013 U.S. venture capitalists invested less than in 2007 just before the financial crisis, 12.7% and 18% respectively (E&Y, 2014).

Almost all of the global industry's 2013 revenue growth and profit came from the 17 US-based commercial leaders (E&Y, 2014). Furthermore, 2013 was the second-best year for biotech financing from public equity markets and VCs since 2003 (E&Y, 2014). This rebound demonstrates the resilience of the U.S. industry due partly to its diversity of finance sources.

US government spending via the NIH (whose budget is over $30 billion) shifted to focus on cancer research and translational medicine, or on the development of drugs for the market by establishing a new organizational institution, the NCATS. And as part of the new healthcare reform bill, the US Congress set aside $1 billion tax credit to small and medium-sized biotechnology firms in 2009 and 2010 for pre-clinical and clinical R&D. So while overall funding has decreased, existing funds where shifted to focus on small firm R&D, translational over basic research, and a greater focus on a specific disease area, cancer.

3.4.4.5 Skill Development

By 2010, the US life sciences industry employed 1.61 million. The key difference in 2013 over 2007 is a broad recognition of the need for interdisciplinary training at universities to address the increasing complexity of the science and ways in which devices and therapies are scaled up in production to serve the market. Traditionally, primarily senior scientist positions filled by chemists and biologists with highly specialized skills served the biotechnology industry. Now, industry is demanding employees with academic training who can support more than one project team and work across multiple areas. Organizations demand strong communications skills where individuals can explain the science effectively to stakeholders, a commercial instead of academic mind-set, identifying and solving real world problems, big data management, creativity and thinking outside the box (Goodno, 2013; Nugent & Kulkarni, 2013).

Producing not only a greater number of scientists, engineers and managers but also those with specific skills demanded by new industries and organizations is one of the challenges cited not only by the United States, but Australia and Canada as well. However, relatively speaking, the United States produces more managers with experience in taking devices and therapies to market than either of the other two countries.

3.4.4.6 Corporate Governance

Firms are now *more* pressured by market demand to become transparent and efficient within the context of scarce resources. At the same time they must demonstrate through evidence the value of their research and potential products. In the past, these processes were more opaque and requirements were less stringent. Investors and payers (governments and private organizations) now demand greater transparency at each clinical trial stage so that they can more accurately value the asset, meaning the drug or medical device, being developed (E&Y, 2014). Precision medicine, adaptive clinical trials and precompetitive consortia are all mechanisms designed for this purpose (E&Y, 2014).

For example, the Accelerating Medicines Partnership is a precompetitive consortia led by the NIH to address Alzheimer's disease, Type 2 diabetes, rheumatoid arthritis and lupus. There are 10 partners including non-profits and big pharmaceutical firms. Specifically, the American Diabetes Association, the Alzheimer's Association, Johnson & Johnson, Bristol-Myers Squibb, Merck & Co., Pfizer, Sanofi, GlaxoSmithKline, Takeda Pharmaceutical Co., Biogen Idec, Eli Lilly, are all engaged in mapping molecular pathways and identifying new drug possibilities. Their goal is to increase the number of new diagnostics and therapies while reducing the time and cost of developing them (NIH, 2014).

In addition, firm's response to these challenges involved both mergers and acquisitions as well as formal and informal strategic alliances. We see that between 2007 and 2013 while mergers and acquisitions remained constant, strategic alliances decreased.

This is because the nature of mergers and acquisitions changed to include many more small biotechnology firms merging with or acquiring each other, in contrast to big pharmaceutical firms merging as in immediate, previous years (E&Y, 2014). And many strategic alliances are notoriously difficult to measure since so many are informal and go unreported (Audretsch & Feldman, 2003).[40]

In addition to leveraging external partnerships, internally firms must address their organizational structure and its capability to achieve the above goals. However, many small firms do not have the capabilities to establish and manage corporate structures valued by investors. These elements include a strong scientific advisory board and for public companies a governing board with clear separation of responsibilities for managerial and stakeholder interests. Finally, the 2008 financial crisis created new rules and regulations, including the US Sarbanes-Oxley Act that influenced similar legislation in other countries, for accounting and disclosure, internal controls and risk management by firms. Based on these developments, we see an increase in the number and nature of formal and informal rules governing state and industry behavior.

3.4.4.7 Conclusion

Several trends characterize the United States' strategic response to the 2008 financial crisis. First, a new strategy stemming from the White House called for a more coordinated and integrated "bioeconomy" to drive future economic growth and sustain the United States' strong economic position globally. The strategy demands greater government-industry coordinating mechanisms. This approach is different from previous policies targeting regulatory changes and R&D financing in specific disease areas. The United States also established the NIH's 27th center, National Center for Advancing Translational Sciences (NCATS) to help translate research and discoveries into commercializable products.

[40] Data sources such as Bioscan, Recap and NSF databases do attempt to capture them. In this dissertation I rely on the E&Y report since they consistently track the same data points annually and the data is free and open to the public.

Second, both government and industry R&D spending decreased from 2007 – 2012, but industry spending began to increase in 2013 based on new drugs coming to market. Third, there is a greater acceptance both within government and industry that the rising complexity of the science and costs of developing new devices and therapies requires an interdisciplinary approach both within university programs and within biotechnology firms. Fourth, mergers and acquisitions remained steady while strategic alliances decreased as firms leveraged external resources or collapsed. Fifth, the public and private sectors are embracing new approaches to creating value in products including adaptive clinical trials, precision medicine and precompetitive open source models.

3.5 Conclusion: Industrial Restructuring and the "Competition State"

After the 2008 global financial crisis the bioscience industry restructured, the state's role changed, and the rate of institutional change increased. Many firms in weak financial condition or with few complementary assets ceased to exist. Those that remained leveraged external resources, outsourced non-core functions or were acquired. This rationalization enabled companies to focus on products and technologies with strongest commercialization potential.

While *competition* for finance, labor and markets increased as expected, so did *collaboration* among competitors and non-competitors. This tension is common in science-based industries like biotechnology where no single firm can pursue R&D and commercialization on their own. The complexity of the science and the difficult, costly process of bringing products to market through stringent regulatory requirements are obstacles. This condition draws the state in to solve market failures of information asymmetry, uncertainty and scarce finance. The Schumpeterian Competition State helps to understand these new roles.

Australia, Canada and the United States shifted strategies towards high risk/high reward research and away from "R&D Democracy." These countries created formal mechanisms that facilitate information and knowledge-sharing and leverage resources among state agencies, public research organizations and firms. Industry in partnership with the state established precompetitive open source models to spur learning and knowledge development. These new institutions were designed to reduce uncertainty, risk and improve valuations of discoveries with market potential. All three countries recognized a need for talent that brings interdisciplinary knowledge and skills to solve real world problems. And each country explicitly linked support for biotechnology with a stronger global economic position. But a closer examination reveals diverging tactics and institutions among countries.

Countries differed in their financial mechanisms, industry growth through local firms or FDI, and niche versus broad based bioscience approaches. Both Canada and Australia lack the density and diversity of financial sources needed to sustain the industry's growth. After the financial crisis both states reinforced their government-backed, privately managed VC model to compensate. At the same time, the United States leads with privately owned and managed VCs.

Canada's and Australia's strategy combines funding for university R&D and spinout firms, public research organizations (PRO)-industry collaboration projects, and FDI attraction to bring financing and knowledge spillovers. The United States' first mover advantage developed a local biotechnology industry first that later attracted MNCs. Since it is a free pricing prescription drug market it offers higher profit margins that are attractive to firms globally. US firms have weathered the crisis more successfully than those in Canada and Australia particularly because of the diversity of financing options. These include mergers and acquisitions, alliances, VCs, public R&D, the stock market and new drugs coming to market in 2013.

Each country chose a different bioscience niche. Canada concentrates on human health, less on agricultural and environmental biotechnology. Australia's choice involves two approaches. One requires investment in R&D related to value-added products and technologies derived from traditional industries of agriculture, mining and the environment. The other focuses on future industries tied to human health advances. The United States' strategy embraces the broad concept of "bioeconomy" and its multiple industry applications from human health to industrial biotechnology.

Canada is shifting from traditional support for university research and FDI tax incentives to one that embraces the Competition State's pursuit of technological innovation and correcting market failures. The country aggressively moved to support

PRO-industry collaborations to commercialize new technologies while reducing basic research. However, the negotiation process was fragmented and arms-length even though input was sought from industry organizations like Biotech Canada and CME. Universities and the NRC bring a tradition of basic R&D and science policy work with a culture that often clashes with industry. These organizations were less involved in building consensus. Provinces were asked for input but the federal government admitted it needed to improve its coordination with them. Major qualitative changes in R&D and commercialization mechanisms as well as in overarching goals were made. But the fragmented bargaining process combined with a decrease in both public and private sector biotechnology financing may compromise industry sustainability.

Australia announced just after the financial crisis in 2009 a 10-year reform agenda facilitating its transition to a knowledge economy. Of the three countries it was the only one to increase public R&D spending in biotechnology and medical sciences. Australia changed its national innovation system by consolidating financial institutions including its VCs and creating biotechnology Action Agendas. The government also subsumed The Office of the Chief Scientist and CSIRO under Australia's Department of Industry. This organizational change signaled the federal government's belief that science should serve industry in order to sustain Australia's global economic competitiveness. As a result basic scientific research may suffer and jeopardize the country's interest in becoming a country that leads through groundbreaking discoveries.

The United States established a new paradigm. It sees biotechnology as a tool with which to create a broad-based "bioeconomy". Biotechnologies applied across industries will sustain the country's economic strength globally while reaching social goals under an increasingly government-funded healthcare system. This concept differs from previous understandings that narrowly focused on biotechnology and a free market drug pricing system. The new strategy calls for various government agencies to coordinate and collaborate among themselves and industry, leverage resources, and prioritize biotechnology in their budgets. But federal R&D spending has steadily decreased since the financial crisis despite new institutions like the National Center for Advancing Translational Sciences (NCATS). Prioritizing *both* broad-based industrial growth driven by technological innovation *and* access to affordable healthcare will require different ways of organizing economic activity. It may prove unfeasible.

The role of the state changed after the 2008 global financial crisis breaking with path dependent trajectories in Canada, Australia and the United States. The crisis left few alternatives from which to choose in order to survive and remain competitive. The three countries actively searched for and shared lessons learned globally through organizations such as the OECD and WTO as well as domestically from previous policies and sub-national experiments. The different bargaining approaches stemmed from paradigm shifts toward the role of the state in facilitating knowledge-based industries.

The next two case study chapters examine Canada's established and aspiring bioscience provinces within this context. They explicitly test hypotheses related to the presence and strength of a KOST in influencing degrees of and changes in bioscience commitment strategies. Sub-national cases are better suited to these micro-level comparisons and tests.

CHAPTER 4

QUEBEC AND ONTARIO:

LOCAL RESPONSES TO GLOBAL SHOCKS

4.1 Introduction

Quebec and Ontario, the two oldest and largest industrial centers in Canada, maintained different commitment levels to bioscience through the 2008 global financial crisis (GFC). Quebec sustained a high commitment linking institutional changes across all three areas of finance, skill development and corporate governance. Ontario continued its mixed level of commitment with changes in finance and skill development but not corporate governance. This chapter examines the role of a knowledge-oriented strategy team (KOST) and policy communities in this dynamic process.

Quebec's traditional strategic approach to industry development provided the foundation for a coordinated response to the 2008 global financial crisis. A few strong KOSTS were present in Quebec before the crisis. These teams were located in Montreal, Quebec City and Sherbrooke where pharmaceutical and biotechnology industries were evolving. KOSTs began to develop ties among each other after the crisis with the help of BioQuebec and the Ministry of Economy, Innovation and Export creating a meta-network. This coordinative process *sustained Quebec's holistic, high commitment* to its bioscience industry.

Change occurred despite a sudden decrease in industry size and financing. The KOST quickly regained consensus around new industry and economic development goals by deliberating regularly, creating incentives and sharing knowledge about how best to leverage existing resources. The process generated a new understanding of stakeholder interests and preferences as well as how to frame challenges and opportunities. It produced new goals focusing on personalized medicine and technology commercialization. The results are changed but complementary institutions facilitating collaboration projects, interdisciplinary training, alliances among firms, and government and university R&D.

Ontario suffers from old industrial structures framed within a “states versus markets” mindset applied to bioscience. A weak KOST existed prior to the 2008 global financial crisis led by the Toronto Biotechnology Initiative (TBI), the province’s industry association at the time as it adapted to capture opportunities offered by the new biotechnologies. After the crisis multiple strategy communities began to vie for influence and resources. In 2010 the incumbent industry association renamed itself Life Sciences Ontario (LSO) and reorganized to encompass a broader societal membership from students to large pharmaceutical firms. At the same time a new industry association, Ontario Biotechnology Industry Organization (OBIO), established itself speaking for a missing constituency - small and medium-sized biotechnology firms stuck without financing or much needed commercialization expertise. The two associations now compete instead of coordinate to represent industry through a single voice.

While the competition has increased stakeholder representation and raised awareness of problems specific to small and medium-sized biotechnology firms, it weakened relations with the lead government ministries at the time. These included the Ministry of Economic Development, Trade and Employment and the Ministry of Research and Innovation. Government views this division as inhibiting the ability of Ontario to reach its potential. Not only does this fragmentation slow knowledge spillovers among bioscience firms within the province, but externally it sends mixed signals to potential FDI. The ministries are now incentivizing the industry associations to either coordinate or merge. These multiple policy communities have engaged in disruptive social learning as they strive to capture the benefits of biotechnology but the fragmented nature of the bargaining process *maintains Ontario’s mixed level of commitment* to the bioscience industry.

Empirical results reveal that both provinces seek more collaboration projects, interdisciplinarity in R&D and university degree programs, diversity of financial resources, and global branding as biopharma hubs. Biotechnology firms and big pharmaceutical companies are creating more alliances and new forms of corporate governance structures. While both provinces seek to foster their local biotechnology industries and attract FDI, Ontario focuses more on creating and keeping local firms while Quebec emphasizes attracting and keeping FDI.

In this chapter I briefly trace the evolution of bioscience strategy and institutional development in each province. I then delve more deeply into the 2007 – 2013 time period capturing strategic responses to the 2008 financial crisis. The evidence unveils differences even though both provinces are attempting to balance their traditional industries of agriculture, automotive and plastics with knowledge-based industries such as bioscience. This difference is to be expected as each inherited diverse principles and practices related to industrial policy. Quebec brings a tradition of state intervention and coordination through sector plans similar to European and specifically French approaches. Ontario applies neo-liberal market-led governance modes. Each method has been effective in some industries like plastics and automotive in Ontario and aerospace and bioscience in Quebec.

Both provinces struggled over time to sustain early success in their bioscience industries. Quebec's experience in balancing competition and coordination created rules and norms that enabled it to respond more quickly to the 2008 global financial crisis. It strengthened its KOST by tightening coordination among bioscience organizations distributed throughout Quebec especially in Montreal, Quebec City, Laval and Sherbrooke. The process has enabled the province to maintain its high level of commitment to the bioscience industry that is fraught with market failures.

4.1.1 Descriptive Statistics: Comparing Quebec and Ontario

After several years of growth, Quebec's and Ontario's bioscience industry contracted in response to the 2008 global financial crisis.[41] Ontario's bioscience industry grew between 1999 and 2009 from 111 to 140 biotechnology firms including Biovail, Cangene, Hemosol, and Vasogen. The industry was sizable as its portion of the

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[41] Finding comparable bioscience industry data is difficult since countries and regions tend to track different types of firms differently. The OECD has developed a common system for data gathering. I combine federal, provincial and OECD data to develop a picture of industrial structure and development.

province's GDP reached 35 billion dollars, one-third of which is derived from exports. [42] The province also spends a considerable amount on science and technology R&D reaching 2.23 per cent of GDP in 2010. The industry is broadly comprised of 850 firms including those in biotechnology, big pharmaceutical companies like GlaxoSmithKline, Roche, Sanofi Pasteur, Johnson & Johnson, GE Medical Systems and Genzyme, and 670 medical and assistive device companies all of which employed more than 40,000. Most if not all pharmaceutical companies are foreign-owned.

Quebec's bioscience industry was valued at $23 billion of total provincial GDP in 2008. Its R&D investment in science and technology was significantly higher than Ontario's reaching 2.49% of GDP. The number of biopharmaceutical firms in Quebec totaled 145 including Shire Biochem, Axcan, and Nexia and employed over 20,900 workers (McNiven, 2001). The industry included 28 pharmaceutical firms, mostly MNCs and employing almost half the industry, 67 health-related biotechnology firms employing about 11% of the industry's workforce, and 50 generic pharmaceutical and contract manufacturing firms (Québec, 2010).[43] These data indicate a growing sector since in 1999. But by 2008 Ontario and Quebec suffered immediate losses from the financial crisis. The number of firms decreased from 98 to 84 in Ontario and 87 to 78 in Quebec (E&Y, 2009).

The structure of bioscience clusters reconfigured over time and more quickly after the crisis. Montreal and Toronto's biotechnology clusters housed two different subsystems, one more recent than the other. The traditional system included large pharmaceutical MNCs and their research labs contracting out work to universities and research hospitals while CROs provided the MNCs with clinical services. The more recent network includes small biotechnology firms, VC companies and university researchers. Universities typically spinout these firms while VCs finance them at different stages of the product value chain. But in 2000 these two systems did not necessarily interact and rarely coordinated (Niosi & Tomas, 2003).

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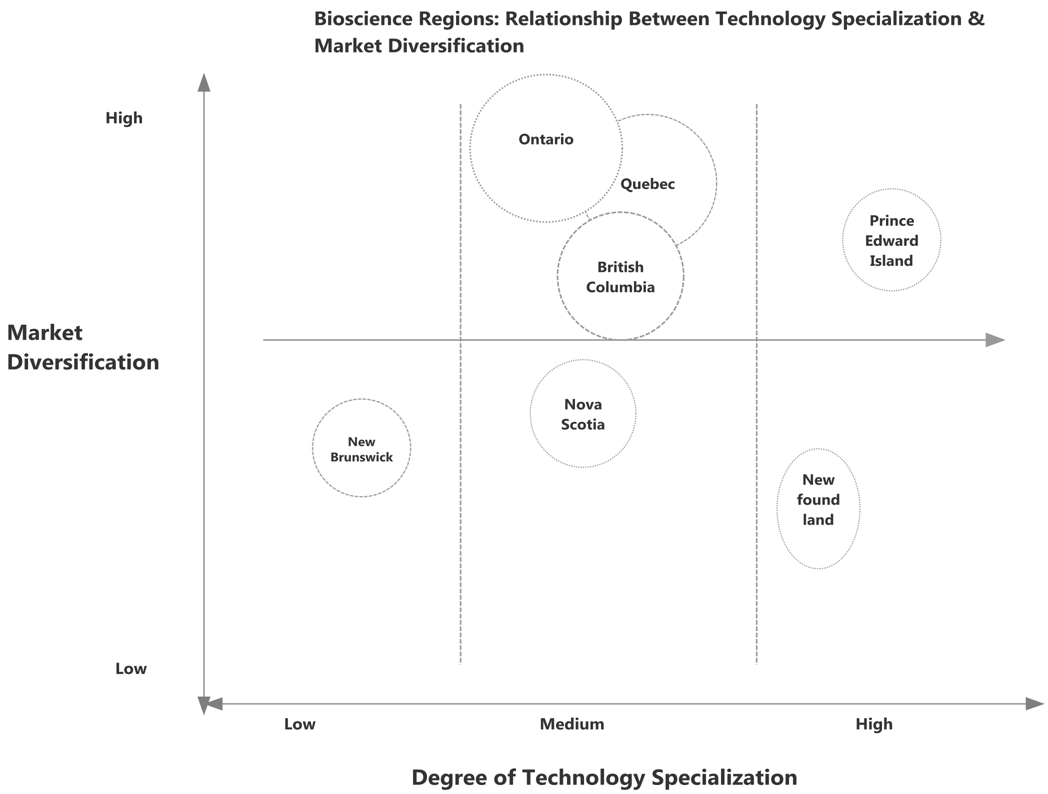
[42] See http://www.biotech.ca

[43] Ibid.

MNCs had developed R&D alliances with overseas biotechnology firms based on mutual interests and complementarities rather than with local firms (Niosi & Bas, 2001). At the same time, local small biotechnology companies engaged in alliances with foreign-based pharmaceutical MNCs for similar reasons. The international nature of the two subsystems were driven by functional proximity in areas like cancer research or medical devices versus geographic (Rallet & Torre, 1999). But a cluster was developing as firms were both competing for human and financial resources and collaborating on issues related to shared facilities, legal and other support services. By the mid-2000s these subsystems in Quebec began to connect and after the financial crisis those firms still surviving ended up restructuring to include more alliances.

In addition to industry size and type the snapshot below situates select Canadian bioscience regions in relation to each other and helps make some further comparisons. It correlates the level of technology specialization with level of market diversification by region. However, the number of application areas and level of market diversification are estimates based on industry reports rather than discrete values. Ontario and Quebec's place in the graph result from strategies favoring investments in technologies with application to many markets within human health and medical devices. Each represents an effort to minimize risk while capturing opportunities offered by the industry. The results indicate that far from pursing a single strategy, provinces choose among several paths.



Note: General market areas include - Agricultural Biotech, Human Health, Medical Devices, Bioinformatics, Industrial & Environmental; Marine Biotech. Degree of specialization based on statements in strategies. NB = Plant, Industrial/Environmental/Marine; NL = Bioinformatics, Marine Biotech, Industrial/Environmental;NS = Human Health, Medical Devices; PEI = Agricultural Biotech, Human Health, Marine Biotech; QC = Human Health, Medical Devices; Ontario = Human Health, Medical Devices; BC = Human Health, Industrial/Environmental, Agricultural Biotech. Circle size based on # regional/cluster participants.

Figure 4 Bioscience Region: Technology Specialization & Market Diversification

Source: Data gathered by the author from industry reports and Statistics Canada.

4.2 Background: 1980s Discovery of Recombinant DNA Techniques

4.2.1 A Problem-Focused Approach: Capturing the Benefits of a New Technology

In the 1980s Quebec's and Ontario's economies were driven by traditional industries like agriculture, automotive manufacturing and plastics while most R&D was taking place in the university system. Pharmaceutical MNCs were manufacturing and selling drugs to the provincial formularies. The federal government was negotiating CAFTA and subsequently NAFTA agreements with the United States to benefit from an open trading system primarily as a way to enhance its competitive position globally.

Provincial governments were designing various strategies and policies as well. By 1990 Ontario elected a new government, the New Democratic Party, which brought with it ideas to develop Sector Strategies linking the public sector with industry including biotechnology (Gertler et al., 2002; D. A. Wolfe & Gertler, 2001). However, the idea of a formal industrial policy with specific plans was contrary to Ontario's norms supporting market-led competitive practices. Quebec on the other hand, had transitioned to more government interventionist approaches as early as the 1960s and aggressively so in the 1980s in knowledge-based industries including bioscience and aerospace. The province's early experience with the public sector strategically engaging with industry in specific industries prepared it for its response to the 2008 financial crisis.

The problems Canada and its provinces faced in the early 1980s centered on how to capture the opportunities stemming from the discovery of recombinant DNA techniques. The country decided to focus first on agricultural and environmental applications with some attention to human health. Both provinces confronted this challenge with difficulty especially since they are large, older industrial economies. Vested interests in rival industries like agriculture, automotive, textiles and plastics had to be balanced with those of the newer industries like aerospace, biotechnology and ICT. The threat of path dependence relying on older industrial structures and logics was very real. This section traces how Quebec and Ontario responded to these challenges and how they learned from the process. It lays the groundwork for understanding each province's reaction to the 2008 financial crisis.

4.2.1.1 Quebec: The Unsustainable "Good Years"

Unlike Ontario, Quebec distinguished itself early in the 1980s as an aggressive proponent of the new biotechnology.[44] Both the provincial and federal governments reformed their patent legislation. Provincial agencies were quick to create tax credits and R&D financing to attract FDI in biopharmaceutical R&D and generic drug manufacturing. Eventually a triggering event occurred in 2001 that catapulted biotech in Quebec. The scientist-entrepreneur, Roberto Bellini spun-out a company from the Institut Armand-Frappier that developed the first HIV-AIDS drug known as 3TC. BioChem Pharma eventually sold the drug to Shire Pharmaceuticals of the United Kingdom. Funds from this sale were reinvested in Quebec's biotechnology cluster that resulted in a handful of new firms and thousands of jobs (Québec, 2010).This sale demonstrated possibilities for success to the rest of the local biotechnology community. FDI and new local firms grew in number as a result.

The province struggled to sustain these successes by the early-mid 2000s. At this time rules governing R&D financing lagged behind industry and university demands. The province still considered funding university R&D key. There was also an over-reliance on the initial success of BioChem Pharma that raised unrealistic expectations. A lack of second-generation entrepreneurs and skilled managers revealed gaps in competencies especially in how to attract risk capital and to commercialize new products.[45] Initial heavy government intervention in financing basic and applied research combined with late-stage private sector investment in drug development left gaps in financing needed to bring drugs from "cradle-to-market." External global shocks like the 2001 ICT industry crash increased uncertainty and risk. VCs who lost investments were reluctant to take on

[44] Quebec's 1960s Quiet Revolution advocated new values of state intervention and planning (Bélanger, 2000). These values informed the role of the state in spurring biotechnology in the 1980s especially as the province's economy was struggling. Traditional manufacturing and agricultural industries were increasingly exposed to global competition and its rival, Ontario, began to attract more FDI. Elected officials from all levels of government and business leaders devised a strategy outlined in the Picard Report to transition Montreal's economy towards a knowledge-based one driven by aerospace, pharmaceuticals and ICT (Picard, 1986).

[45] Author Interview, Quebec City, Quebec, October, 2012.

risk in an even more uncertain industry like biotechnology. Despite competing interests, social learning did occur as government-funded, privately managed VCs figured out how to restructure financing over time to gain greater return on investments and universities learned more about how to measure risk and reward.[46]

Four factors drove Quebec's cluster emergence. First, both national and provincial leaders shared the political will to improve Canada's economic competitiveness by transitioning from a resource-based economy to a knowledge-based one. Second, Quebec exercised some influence on federal regulations governing IPR while simultaneously coordinating its own strategy to expand patent protections for its firms as well as R&D spending. Third, the provincial government implemented a deliberate strategy around a particular knowledge area, pharmaceutical development, building on the success of large, incumbent MNCs and local firms already operating in the province. Fourth, the existence of several universities with medical schools, hospitals and bioscience-related departments engaged in basic research provided a foundation for cluster emergence and a critical trigger through the sale of BioChem Pharma. The above processes resulted in two networks, one dominated by large pharmaceutical firms and their relationships with university researchers and Clinical Research Organizations (CROs), and the other led by SBFs and their collaborative relationships with universities and CROs (Niosi, 2000; Niosi & Tomas, 2003).

Quebec pursued a high commitment strategy during the 1980 – 2007 time period despite challenges associated with learning about and capturing new opportunities. It coupled financing and skill development investments with industry's efforts to improve its capacity to innovate. This disruptive social learning and coordinated bargaining process involved a policy community comprised primarily of provincial agencies, biopharmaceutical MNCs, and the Office of the Chief Scientist aligned with the goal of securing cheaper drugs and creating new therapies. The 2008 financial crisis tested existing learning structures and commitment strategies.

[46] Author Interview, Montreal, Quebec, October, 2012.

4.2.1.2 Ontario: The Province that "Does Not Change Well"

In contrast to Quebec, Ontario made incremental policy changes rather than a change in overarching industrial development goals during the 1980s. There was no formal bioscience strategy except one produced in 1995 that was not fully developed. Ontario traditionally has led a fragmented political bargaining process. The province and industry had not established social norms or mechanisms for sharing lessons learned, jointly developing sector strategies and creating incentives for industry to engage. By 1990, however, with the election of the New Democratic Party (NDP), the province began an experiment. Ontario was experiencing an economic recession at the time and adjusting to the opportunities and challenges presented by NAFTA. With an open trading system came attempts at industrial restructuring in areas of automotive, agriculture and manufacturing especially in the face of competition from Asia and the United States.

In 1992 the NDP and Parliament moved against tradition by approving an *Industrial Policy Framework* and a Sector Partnership Fund with a budget of $150 million over six years to support specific Sector Strategies jointly with industry. The strategy was intended to change the business culture within Ontario to embrace more collective responsibility and to engage in social learning processes that could become the basis for sustained competitiveness. The overarching goal was to create high wage, high value-added jobs and strategic partnerships with industry. One way to do this was to increase productivity through continuous product and process improvements across networks of firms and industries within the province rather than reducing the costs of existing industry (Laughren, 1991; D. A. Wolfe, 2002)..

The strategy generated mixed results and eventually was cancelled in 1995 with the election of a Conservative government. While firms within sectors learned more from each other and developed useful relationships, sector strategies were not implemented except in those areas that had begun a similar process much earlier than the 1992 framework. The Conservative government kept or revised the strategy in emerging sectors like biotechnology even though few sectors reached Wolfe's idea of a "negotiated order."[47]

In 1989 various policy communities were forming and evaluating prospects for biotechnology prior to the 1992 Sector Strategies. Government produced its Green Paper: "Biotechnology in Ontario – Growing Safely," which addressed biosafety and environmental issues (Labour, 1989). Industry formed its first association from very organic beginnings in the Toronto Biotech Initiative.[48] The Ministry of Health and Long-Term Care continued to administer health R&D funding as far back as the 1970s.

Despite these gains, Ontario did not take a strategic approach towards growing the industry. There is little evidence of significant investment in finance, skill development and firm competencies. As one interviewee noted:

> Ontario did nothing until the late 1990s and then the government cut university funding to focus narrowly on health research through the Canadian Institutes of Health Research (CIHR). The universities then came later to government demanding more support for research generally so Ontario established the Science and Technology Division within the Ministry that evolved into the Ministry of Innovation and Research.[49]

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[47] A critical change was an increased focus on the provincial government and its agencies strengthening its existing working relationships with specific sectors and creating new ones in growth industries like biotechnology (D. A. Wolfe, 2002). The Sector Partnership Fund was designed to draw in key sector actors including a formal industry association and broad-based stakeholders to develop and implement a strategy. The Cabinet Committee on Economic Development would then approve the strategy. Specific initiatives could be submitted to the Cabinet by the sector for funding. Ultimately small and medium-sized firms did not have the financial resources required to match government funding of initiatives and were reluctant to submit proposals given the complex bureaucratic process while large firms did not see significant benefit. In the end a lack of incentives and a reversion back to old ways of lobbying government for traditional tax incentives occurred (D. A. Wolfe, 2002).

[48] This organization began as an informal, grassroots initiative by both the city's economic development agency and interested individuals from service providers like investors, banks, and law firms. These individuals met regularly every month and eventually expanded beyond Toronto offering mentoring opportunities to scientists spinning out companies from university.

[49] Author Interview, Toronto, Ontario, March 25, 2014.

Roger Martin was an influential agent within government during this process. He raised the profile of R&D and innovation as drivers of Ontario's future growth by helping to create the Ministry of Research, Innovation and Prosperity.

By the early 2000s Ontario had more diversification of firms and VCs but nowhere near the level expected.[50] But similar to Quebec and the individual scientist-entrepreneur, Francesco Bellini of BioChem Pharma, Ontario had its success story. In 1999 David Young applied his science background to found ARIUS Research based on a proprietary technology platform that generated and selected therapeutic antibodies based on their activity. This platform is useful in treating cancer and other diseases. Over nine years the company raised $30 million from investors. It was on the verge of bankruptcy but survived. In 2008, Roche, a global pharmaceutical and diagnostics company headquartered in Switzerland, purchased ARIUS for C$191 million.

This sequence of events was viewed initially as a success and a potential pathway for other Ontario start-ups. But it did not result in reinvestment of funds from the sale into the local biotechnology community as Biochem Pharma did in Quebec. The stated intention by Roche was to keep the Ontario location and continue to conduct R&D there. It eventually closed down leaving the impression that Roche really was just interested in purchasing the firm's 400 compounds.[51] This case is important in that it reveals the struggles that local economic developers confront when the goal is to keep existing, high-paying, highly skilled positions and expand them.

In the 1990s while Quebec was increasing its bioscience R&D funding, devising aggressive tax incentives and patent legislation to attract FDI, Ontario cut funding and narrowly focused on cancer research. Individual pharmaceutical and biotechnology firms designed strategies to sell to the provincial healthcare system and its formulary as well as to international markets, not to other domestic markets. Innovation typically took place in healthcare services and processes rather than through the commercialization of new products. While there were a significant number of firms, most had little cash and in the 1990s only one local firm demonstrated the typical path to success.

[50] Author Interview, Toronto, Ontario, March 25, 2014
[51] Author Interview, Toronto, Ontario, March 24, 2014

These trends combined with other social norms that constrained the provinces. In Ontario a “cultural preference” for university research in the hopes that individual scientists would spin out companies reduced government funding of industry collaboration projects. Reliance on the logic of older, traditional industries limited biotechnology’s growth. Medium-sized firms so necessary to attract FDI and to grow the industry did not develop though a significant number of small start-ups emerged.

Similar to Quebec, Ontario had two different industrial structures. One was led by large pharmaceutical MNCs and their relationships with CROs and universities while the other was led by small startups and their relationships with VCs and universities. But differences even in these networks existed. In Quebec VCs were largely government-funded and privately managed. In Ontario they were mostly privately financed and managed especially after a “bad experiment” in a labor-backed attempt to create tax-free VC funds. In Quebec the sale of BioChem Pharma had positive demonstration effects with the creation of some new firms, while in Ontario ARIUS’ sale did not necessarily lead to greater local investment. Quebec aggressively created favorable patent legislation and increased R&D funding while Ontario had no real strategy and decreased funding.

During this time Ontario relied on its legacy of market-based institutions that were successful in supporting traditional industries but not so much in launching complex, science-based ones like bioscience where uncertainty is high and innovation occurs rapidly. By 2007 with few credible commitments aside from the MaRS facility established in 2005 and designed to help startup ventures with broad economic and societal impact, Ontario was following a fragmented path dependent trajectory, still struggling to learn how to adjust to a globalizing world.

4.3 The 2008 Global Financial Crisis: A Critical Juncture for Quebec and Ontario?

The 2008 financial crisis created a critical juncture for both provinces in their efforts to facilitate bioscience industry development. Quebec reinforced its high commitment strategy with new ways of financing, developing necessary skills and corporate competencies. After the crisis it further mobilized and coordinated the smaller bioscience organizations that existed in Montreal, Quebec City, Laval and Sherbrooke. Ontario maintained its mixed commitment strategy where decoupling of institutions remained and fragmented negotiations continue despite new policy communities arising.

Quebec strengthened its learning structures linking public and private sector organizations and leveraging their respective knowledge sources. Ontario's social norms continued to reject industrial policies as interfering in rather than catalyzing some sectors. This mindset prevented coordination among policy communities. Social learning structures that existed prior to the 2008 financial crisis prepared Quebec to respond quickly with new overarching goals and complementary institutions. Ontario remained trapped in old ways of organizing its economy despite sporadic success.

4.3.1 Context: Industrial Reorganization and Strategic Responses

By 2007 the global biotechnology industry was reconfiguring itself to take advantage of the few drug development opportunities in the pipeline. Companies with drugs in stage three clinical trials were particularly attractive as either acquisition targets or potential allies with large pharmaceutical firms. While industry was restructuring, the 2008 financial crisis further exacerbated the process, constricting risk financing and forcing small firms with little funding to closed down or seek government R&D funds while others sought different types of alliances to secure financing particularly with big pharmaceutical firms searching for high potential assets, or potential therapies.

At the provincial government level, while both Quebec and Ontario suffered bioscience industrial decline, each responded differently to the financial crisis. Quebec government agencies, industry associations and individual lead firms relied on their tradition of coordination and created public-private partnerships to help refocus the industry and reduce transaction costs. But it is still too early to determine if they are restructuring effectively.

While Ontario developed a written strategy during this period, the perception by industry is that the province had no strategy, opting instead to rebuild its infrastructure and let industry lead. While neither approach guarantees industry sustainability they reflect each provinces' inherited principles and practices, learning and bargaining processes all of which have led to particular strategy choices and industrial change. I argue that Quebec's institutions relative to Ontario's represent a higher commitment.

4.3.1.1 A Problem-Focused Approach: Understanding Opportunities, Leveraging Scarce Resources, and Creating Competencies

By this time, the provinces were focusing on human health applications in areas of cancer, stem cell and other major diseases. The challenge was how to leverage very scarce financial resources globally to create capacity in different skill development areas and to share risk in order to capture opportunities within a highly competitive global environment. While the opportunities by 2007 were defined more by their commercial possibilities than by the production of new knowledge through basic research, scarce risk financing forced small biotechnology and big pharmaceutical firms to focus on core capabilities and high potential therapies. Key questions include: How to reconfigure industry governance and institutions to support R&D with highest prospects for success? How to grow the local industry base as opposed to selling intellectual property via licensing to FDI, thus avoiding the "growing them to leave" trap?

At the same time, the provinces were trying to manage technological and economic uncertainty to create a stable industry. Both provinces pursued different path dependent strategies before and after the 2008 global financial crisis (GFC). Quebec maintained its high commitment to bioscience despite major changes while Ontario continued a mixed commitment.

4.3.1.2 Quebec: Picking up the Pieces

Quebec maintained its high commitment to bioscience and quickly made substantive changes in its strategy in response to the damaging effects of the GFC. A strong KOST expanded to include new stakeholders representing bioscience clusters in Montreal, Quebec City and Sherbrooke. This team negotiated not only their own strategies but a new provincial one led by the Ministry of Economic Development, Innovation and Exports (MDEIE) and the Office of the Chief Scientist.

Revised overarching goals included “mobilization, innovation and prosper” (MDEIE, 2010). The strategy was designed to strengthen institutional complementarity among finance, skills development and corporate governance. To do so it favors collaboration projects requiring financing along the value chain, scientific and technical skills directly linked to industry demands, and alliances among firms, PROs and universities. This approach coupled with individual firm strategies and a favorable business environment is designed to restart industry growth.

Between 2005-2010 the number of human health-related biotechnology companies declined by about 21% and employment dropped by 48% (BioQuebec, 2008, 2012).[52] Between 2001 and 2008 the number of biotechnology firms decreased from 110 to 67 and employment fell from 3,000 to 2,300. Between 2006 and 2011 pharmaceutical and medical manufacturing jobs declined by 28% from 10,422 to 7,549. BioContact, the industry’s most important annual conference, reported that attendance declined from close to1,000 prior to the financial crisis to 300 in 2012.[53] This downward trend signifies that Quebec firms merged and acquired each other, folded or restructured into other organizational types like VCs.

Quebec’s strong KOST responded to the volatility by learning about the challenges and how to address them. Quebec sought greater coordination among regional actors in areas of knowledge development and finance. It chose a general application area, human

[52] Additional data obtained during discussion with the Quebec Ministry of Finance and Economy in October 2013.
[53] Author interview, Quebec City, Quebec, October, 2012.

health, and a knowledge niche, personalized medicine, which is underpinned by genomics.[54]

Its strategy also seeks to spur growth through stronger ties to other clusters within Canada especially Ontario and globally including California and Sweden. The nature of these ties includes FDI, joint R&D, co-investments and market access to skills and finance. In 2011, the province created its first Office of the Chief Scientist to manage the province's three research funds including nature and technology as well as health while promoting and financially supporting research, knowledge dissemination and researcher training in Québec. Finally, in 2012 the Quebec government abolished its "15-Year Rule" since costs of procuring brand-named drugs were exceeding tax collections from FDI.[55]

Four trends characterize this period: a severe financial crisis; small biotechnology firms closing down or changing their business model to focus on fewer NCEs and niche areas; MNCs closing their R&D facilities, in some cases reconfiguring them into investment organizations; VCs investing in shorter time-spans along the drug development value chain to capture highest revenue opportunities; and, national institutions reconfiguring towards commercialization efforts while provincial institutions expand and coordinate networks of partnerships among industry, university and government.

I argue that Quebec's response to the 2008 financial crisis involved disruptive social learning along with a relatively coordinated negotiation process. New institutions were created and others changed but conflicting interests underpinned the process.

Three leading organizational institutions–the Office of the Chief Scientist, the MDEIE, and BioQuebec, the industry association - developed their own strategies, which ultimately appear quite similar. For example, in 2012 the Office of the Chief Scientist called for Quebec to differentiate its bioscience "ecosystem" internationally, increase financing for innovative technologies, create more partnerships among the various

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[54] Author Interview, Quebec City, Quebec, October, 2012

[55] Details of the rule can be found here:http://www.canadiangenerics.ca/en/news/docs/eliminationof15-yearrule.pdf

bioscience stakeholders and promote on an international scale Quebec's new business model to collaborate with stakeholders (Quirion, 2012).

The province continued to develop its general three-year research and innovation strategy from 2007-2010 and 2010-2013, adding "mobilization" to its theme of innovation and prosperity (MDEIE, 2006, 2010). This change further indicates the province's recognition that coordination and mobilizing resources are necessary during times of severe global competition and financing shortages. Its $122.7 million bioscience strategy established in 2009 complements the overall R&D strategy, emphasizing partnerships especially in pre-competitive and clinical research areas, retaining and attracting skilled labor, local – global collaborations among firms as well as between firms, university and government research organizations in order to both adapt to and compete within new global market conditions (Québec, 2010).

Specifically, the strategy identifies five objectives: Encourage firm spin-offs from R&D; support both small biotech firms and big biopharmaceutical companies, mostly MNCs with subsidiaries in Quebec; ensure that the province produces and attracts enough skilled labor to support industry needs; emphasize and promote Quebec as a biopharmaceutical cluster globally (Québec, 2010).

In addition to MDEIE, in 2007 the Ministère de la Santé et des Services sociaux (MSSS) developed a unique Quebec Drug policy that takes into account both society's needs for access to low cost, high quality drugs and industry's need to innovate and access markets. MDEIE, MSSS and industry formed a high level, permanent committee to discuss and implement the new policy and to "maintain an attractive, competitive business environment for the Québec economy and businesses in these sectors on the international scene" (Québec, 2010, p. 21).

BioQuebec supports these goals. It joined with Montreal Invivo, the city-level non-profit economic development organization that had been functioning since 2002 but formalized in 2007 just prior to the financial crisis, to advocate for personalized medicine as a common theme. Professor Howard Bergman of the Fonds de recherché du Quebec-Sante initiated the effort in 2010. By 2013 after a highly conflictual negotiation process among stakeholders the province committed $21.1 million to finance the Personalized Medicine Partnership in Cancer (BioQuebec, 2012).[56] The initiative also encourages more creative ways to support local biotech firms and their collaborations with foreign biopharmaceutical companies (BioQuebec, 2012).

Region-industry strategic interaction became more coordinated through new organizational institutions like Montreal Invivo and around common themes like personalized medicine, though not without difficult negotiations aligning interests among the various groups. Government, Bio Quebec and individual firms acknowledged the need for more integrated networks of organizations and research, less silo mentality, as well as new business models that reduce risk and increase return on R&D investment through commercialization.

The resulting institutional configuration continues to shift from a less coordinated, silo approach and one focused on R&D to a more coordinated approach centered on commercialization. However, universities claim that government does not understand the necessary link between basic and applied research leading to innovation. Without increases in funding for basic research to create a strong foundation for new knowledge, they argue, few innovations will materialize.

At the provincial level, the PLQ remained in power from 2003 until 2012, when Jean Charest was defeated and Pauline Marois of the PQ became Premier. During the PLQ's reign, industry stakeholders perceived that the private sector was left to finance more of the bioscience industry than government. However, with the election of Marois and the PQ, expectations are that the provincial government will begin to dedicate more financial resources.

At the same time, the province continued to make advances in basic research. For example, Dr. Mick Bhatia's work at McMaster University discovered how embryonic stem cells could become other cells. Stem cell research generally is considered by some to be as revolutionary in terms of technological innovation and benefits to society as the

[56]Author interview, Quebec City, Quebec, October, 2012.

discovery of recombinant DNA.[57] Though others disagree emphasizing that big bets like these are highly uncertain (Wong, 2011).

However, translating basic research investments into commercially viable therapies and technologies continues to be the ultimate puzzle. For example, though the federal government as well as Quebec invested hundreds of millions of CDN$ in Genome research over the past decade, results in terms of commercializable products did not materialize. This disappointing result was partially due to ineffective financing mechanisms and lack of skilled commercialization managers, as well as to unrealistic expectations related to the level of scientific progress in the basic research component. Despite mixed results in terms of translating basic research into new products and technologies, in 2008, Québec's life-sciences sector was relatively strong and included 400 businesses and 25,000 employees. In addition, 13,000 researchers in publicly funded institutions specialized in neurology, oncology, cardiology, immunology, and genomics.

Recovering from the financial crisis proved to be a formidable challenge even though by 2012 Quebec was engaging in cutting edge basic research and contributing significant discoveries in higher profile bioscience areas from stem cells to bioinformatics. Partly in reaction to the ICT bubble bursting around 2001 and also because the human biopharmaceutical industry lacked success measured by fewer drugs and novel therapies, the PLQ decided to focus their limited financial and technical resources in other industries perceived as more promising.

Large pharmaceutical firms began to outsource their R&D by forming alliances with small biotech firms and establishing their own VC firms that invest directly in NCEs, or, co-invest with other VC companies. These larger firms are also diversifying into product lines beyond pharmaceuticals to include medical devices and technologies. For example, by 2011, Quebec's bioscience industry networks had begun to shift. Pharmaceutical MNCs like GlaxoSmithKline (GSK) and Pfizer closed their manufacturing facilities and instead established VC firms to focus on investing in Canadian DBFs offering promising therapeutics. However, though Pfizer has made four such investments, none have been in

[57] Author interview, Quebec City, Quebec, October 2012.

Quebec, but rather in Ontario and British Columbia.[58] Essentially, larger MNCs have downsized their operations and now are establishing more formal R&D relationships with DBFs whereas before, the larger MNC would internally undertake R&D.

Small biotech firms, on the other hand, began to specialize in niche disease areas and in fewer assets or new chemical entities (NCEs) compared to previous strategies. DBFs were trying to distinguish themselves in order to compete for large pharmaceutical firm investment by focusing on core capabilities. These firms are beginning to more closely link their R&D to market opportunities, for example, in certain disease areas like Alzheimer's or in the orphan drug market.[59] The figure below illustrates these network shifts.

[58] Public Presentation at BioContact, Quebec City, October 2013.
[59] Author Interview, Quebec City, Quebec, October, 2013.

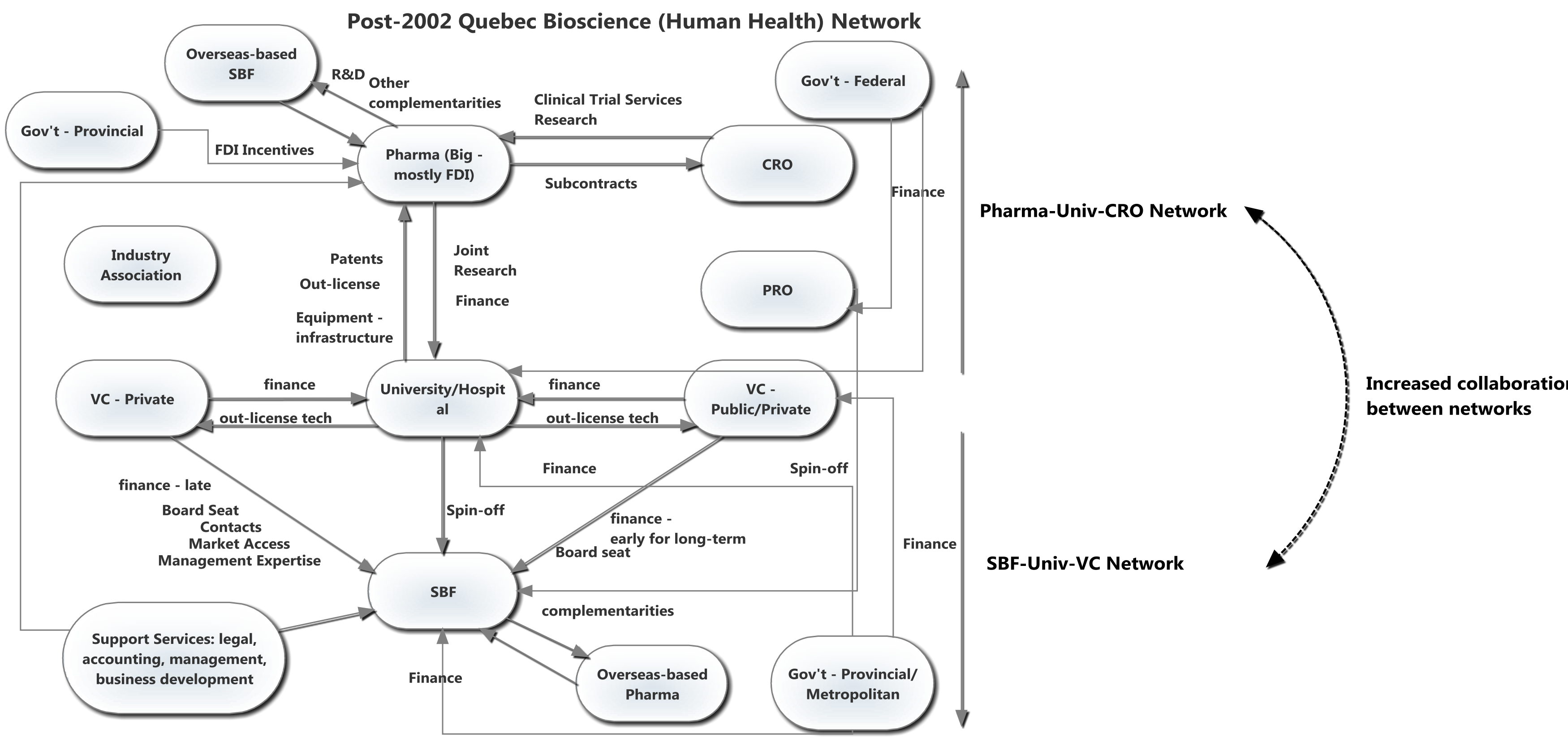

Figure 5 Post-2008 Quebec Bioscience (Human Health) Network

Expanding the KOST

Quebec's history of creating learning structures involves public-private partnerships. These provided a foundation from which the province could quickly react to the harsh effects of the global financial crisis. The province broadened and deepened its strong KOST in response to the sudden scarcity of finance by mobilizing new organizations to form a meta-network around a common vision and commitment strategy.

The ecosystem is comprised of organizations that fund, produce and transfer knowledge. At the provincial level, the Ministry of Economy, Innovation and Exports, Ministry of Research and Innovation, BioQuebec, CQDM, Fonds de recherché Sante under the Office of the Chief Scientist, and Genome Quebec among others play key roles. Federally the National Research Council is prominent.

At the city level, Montreal is the largest bioscience cluster with close to 70 per cent of Quebec's biotechnology firms. Quebec City, Sherbrooke and Laval are small but active. Each grew from policy communities that formalized into what knowledge cluster theorists and practitioners call "cluster facilitators" (Ketels & Memedovic, 2008). These are typically non-profit economic development organizations *led by industry* and with long term financial support from government at all levels and the private sector to catalyze industry growth.[60] Montreal Invivo is an example.

While each cluster developed its own strategic plan, they increasingly coordinated with the MEIE, MRI and the Office of the Chief Scientist around a common vision for Quebec. In other words, Quebec is evolving from small, strong KOSTS distributed throughout a few key cities to a dense ecosystem with strengthened ties among organizations that finance, produce and transfer bioscience knowledge. While the nature of the provincial strategy changed, Quebec maintained its high commitment by continuing to link finance, skill development and corporate governance. The next section evaluates institutional change in these areas after the crisis.

[60] It is arguable that clusters fail when facilitating organizations are led by government that does not share a vision with industry.

High Commitment Strategy: Linking Finance, Skill Development and Corporate Governance

Table 12 details the nature of change in each institutional area. The data reveals that Quebec is shifting towards filling gaps, coordinating and leveraging resources within and among the three institutional areas to support a new phase of internationalization and focus on personalized medicine. This strategic focus is designed to brand Quebec as a global biopharmaceutical hub.

The province is increasing investments in pre-competitive collaboration projects between industry and PROs, immigration programs to attract scientists in support of these projects, interdisciplinary research and education, and leveraging external resources through alliances. The next sections review the evolution of finance, skill development and corporate governance just before and after the 2008 financial crisis weaving in examples of institutional complementarity.

Table 9 Finance, Skill Development and Corporate Governance

	Finance	Skill Development	Corporate Governance
1st Order – Settings	**Biotech R&D spending (US$)**	**Tax Credits – Scientists, Technical specialists**	**Make or Buy Decision – Amount of R&D in-house**
2007/2012 (pre/post financial crisis)	2009 Biopharma Strategy - $122.7 m $1.2 B tax incentives Refundable R&D tax credits	-New tax holiday for foreign researchers in Quebec	Increasingly external
2nd Order – Techniques	**Diversification of finance sources**	**Program Changes**	**Diversity of R&D models**
2007/2012 (pre/post financial crisis)	Continue to fund government-backed VCs like Teralys Capital -new pre-competitive collaboration mechanisms/institutions - CDQM	-Retain and attract highly skilled workers locally and globally -Educate and encourage youth about science careers	-Increase in pre-competitive, open innovation models -Big pharma investing more in university research in specific disease areas (cancer); creating own VCs to invest in Canadian (not just Quebec) assets; outsourcing more R&D to local biotechs; -local biotechs focusing more on 1-2 NCEs, even in-licensing, orphan drugs
3rd Order – Overarching Goals (Paradigm change)	**Core focus shifting (e.g. basic-commercial research, niche application areas, niche science areas)**	**Core focus shifting**	**Core R&D strategy shifting**
2007/2012 (pre/post financial crisis)	Internationalization; Greater Collaboration between firms and PROs; Mobilization/coordination of resources; Pre-competitive collaboration/open innovation; Focus on common theme – personalized medicine	Continue to link directly to industry needs Greater Interdisciplinarity	Greater collaboration between local biotechs& big pharma

Sources: BioQuebec Annual Report 2012; Quebec BioPharma Strategy; Quebec Workforce Development Plan

Did financial institutions change after the 2008 global financial crisis?

Quebec changed existing financial institutions and created new ones after the GFC. The province invested more in government-backed, privately managed VCs and created new research organizations like CDQM to focus on precompetitive collaboration projects jointly funded with the private sector. The focus on public-private partnerships is a shift from separate public investments in university R&D and private VC funds. This shift represents government shoring up scarce financing to maintain its commitment.

Finance is crucial to both R&D and product commercialization in biotechnology firms. Sources of finance come typically from government, VCs, private equity funds, angel investors, stock markets and mergers and acquisitions. VCs play a major role in more established biotechnology clusters like Quebec and Ontario. These organizations typically use exit strategies that enable the VC to sell its shares after a set period of time in the stock market, or, sell to a large pharmaceutical firm for commercialization and distribution. This exit enables the VC to capture profits from a high-risk investment.

By 2007 the Canadian IPO market had been closed and VCs were reluctant to invest in Canadian firms because of weak exit options (E&Y, 2008). VCs instead invested in fewer numbers of firms and those with more promising therapies. This process reduced funding available for small start-ups and those in early clinical trials forcing these firms to partner at too early a stage with larger companies to secure financing. Sometimes the value of these investments was lower than what it should have been because of few financial alternatives to the small biotech firm.

The Quebec Government recognized this weakness and on October 8, 2009 it launched a Biopharmaceutical Strategy. The province's approach towards achieving its goals involved a selective focus on human health and personalized medicine as opposed to all bioscience application areas. It intends to expand financial support along the drug and technology development value chain while creating a market for innovative products through a coordinated health procurement program.

The strategy specifically intends to extend its *financial leadership* by: restricting investments in two-three niches of excellence while developing critical mass; optimizing clinical research and put major funds into translational research in hospitals; and reinforcing Quebec's leadership in the chain of finance (Québec, 2010). [61]

According to the perception at the time, the provincial government's renewed interest in financing the bioscience industry represents a reversal from 2003-2012 when the Parti Libéral du Quebec (PLQ) left financing bioscience to the private sector. One interviewee capture the attitude:

> Now there is a shared understanding that it didn't work. With the Partie Quebecois now in power, there is an expectation that government will back the industry again with financing.[62]

In Quebec key industry associations like BioQuebec develop industry strategy mostly through private sector members and committees with some government participation. City-level economic development organizations like Montreal Invivo negotiate with the Ministry of Economy, Innovation and Exports at provincial level, MRI at national level, city government and the private sector for funding.

However, it crafts industry strategy through mechanisms similar to BioQuebec and mainly with active members like DBFs, large pharmaceutical firms and VCs. The political process involves each stakeholder group negotiating their own interests and bringing different levels of resources to bear as industry identifies shared needs, goals and objectives. While the negotiation process was coordinated and learning occurred it was not without conflict particularly around its chosen theme. Eventually these stakeholders agreed on personalized medicine.[63]

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[61]Specific actions include: Encouraging creation of solid enterprises and well capitalized developed from the "majors; Maintaining long-term investment and maximize value-creation in Quebec in collaboration with global partners; Completing a new fund of risk capital to be able to support projects end-to-end; -Seeding capital and start-up funds (e.g. Anges Capital Quebec) to support biotech and medical technologies; Coordinating risk capital funds with Ontario – Corridor Quebec-Ontario; Facilitating sufficient size, expertise and capacity to intervene in medical technologies; Securing participation of institutional investors in financing after startup.

[62]Author Interview, Quebec City, Canada, October, 2012.

[63]Author interview, Quebec City, Canada, October, 2012.

In the area of finance, big pharmaceutical firms, VCs and government began to change their investment models to one of integrated finance. Increased coordination among these organizations was driven by their need to reduce uncertainty and risk while securing a return on investment. The best way to achieve this goal is to segment out the investment opportunities at each point along the R&D to commercialization chain. Government is trying to fill the funding gaps left by the private sector . During this period investors, DBFs and big pharmaceutical firms began to communicate among themselves at the beginning of a potential opportunity. They agreed on more specific investment roles assigned to each participant. This approach is wholly different from past fragmented models.[64]

For example, Amorchem, a publicly-funded, privately managed VC fund now invests smaller amounts in the early stages of an opportunity to maximize profit. It then sells its shares after two years. Now Amorchem discusses earlier in the process with institutional investors and big pharmaceutical firms to educate them on the opportunity and to secure early commitments for investments after the first stage. Funds like Amorchem now position themselves between university researchers, and, large pharmaceutical firms and other institutional investors. The challenge is "selling the idea of the new model to both sides."[65]

The above example represents a process of social learning and institutional change. Amorchem used to invest in opportunities at the beginning and wait for its return after 10 years by which time other VCs and institutional investors had invested and diluted Amorchem's return. Amorchem took all the risk up front but was not rewarded fully for its long-term investment. Later investors minimized their upfront risk and maximized their return on a fairly large yet short-term investment. In response to these industry challenges as well as to the constraints of their internal organizational structure, Amorchem reconfigured its competitive position. It was content to make smaller returns earlier in the investment process.

[64]Author interview, Montreal, Quebec, October 2012.
[65] Ibid.

In addition to risk finance, individual firms still directly benefited from SR&ED tax credits for R&D, NSERC university-industry collaboration and IRAP grants. Quebec's PROs continued to receive R&D funds from the NRC as well as from Quebec's Ministry of Finance and Economy. However big pharmaceutical firms cut staff and reoriented offices away from generics manufacturing toward R&D investments. Smaller firms were either acquired or failed. Industry interaction with the province is now characterized as more coordinated through the network of strong KOSTS and their projects.

Quebec's FDI promotion strategy led by Invest Quebec explicitly targets medium and large scale investors rather than small firms. It typically funds projects that involve foreign partners and seeks to grow Quebec firms both domestically and internationally.[66] However, since small firms can be the source of innovation, lack of attention by the Quebec government to attracting smaller investors with the potential to grow could lead to lower levels of growth in the short term and cluster instability in the long-term. The province's strategy continues to incorporate FDI as a driver of bioscience industry growth.

4.3.1.2.1 Did skill development institutions change after the 2008 global financial crisis?

Quebec reinforced its skill development strategy after the GFC to attract even more diverse, global talent while balancing this effort with investments in local sources. Firms, universities and PROs require the competencies of scientists and managers with experience in guiding complex projects. Quebec created a new tax holiday to help firms lure needed scientists and technical specialists globally. The province shifted from financing university degrees in traditional biology and medical programs to more interdisciplinary ones. Quebec designed its approach not only to directly meet industry needs but to increase the effectiveness of financial investments. But skills gaps still exist especially in biotechnology firms who lack technology commercialization experience. These changes demonstrate Quebec's relative flexibility and capability to monitor

[66] See:http://www.investquebec.com/en/index.aspx?page=2890

industry change, learn quickly about new opportunities, and combine them with previous experience all through a strong meta-network of KOSTS.

Did corporate governance institutions change after the 2008 global financial crisis?

Firms that survived the GFC maintained their high level of commitment by changing the ways in which they improved their competencies. Companies shifted from internal capacity building to external relationships for this purpose. Quebec's industry association, BioQuebec, advocated this change in its 2008 strategy and 2012 recommendations by prioritizing more biotech-pharmaceutical MNC ties (BioQuebec, 2008, 2012).[67]

Individual firms began to respond to scarce financial resources, rising costs of drug development and fewer blockbuster drug opportunities by searching for new business models that reduce transaction costs, increase access to valuable information, and create efficiencies. These models include project companies, disease teams, large pharmaceutical firm R&D spin-offs and alliances with DBFs. They are quite different from those that dominated the past such as vertically integrated large pharmaceutical firms and DBFs that carefully guarded results of their own R&D and clinical trials. While individual firm strategies still drive corporate behavior, they increasingly include participation in more coordinative institutions with competitors.

For example, stakeholders are creating institutions around the concept of "open innovation" involving information and resource-sharing among industry participants particularly during the pre-competitive phase of product development. However, not all institutions effectively aggregate the interests of all participants. Clearly defining the economic benefits for each as well as intellectual property protections presents barriers.

Industry's reaction to the volatile years from 2007-2012 has been to seek new business models and ways of coordinating and collaborating on both R&D and

[67] The strategy also called for firms to devise aggressive IP protection strategies, improve education of government decision-makers, and influence public policies in support of biotechnology.

commercialization. For example, VCs, DBFs and university researchers are creating "project companies" in addition to vertical companies. Project companies secure resources globally, from finance and management to research partnerships and direct them to commercializing a single product or NCE discovered by a university or entrepreneur-scientist. This approach enables more flexibility to secure the best talent and financing to bring promising drugs and technologies to market. The project company is a form of process innovation in terms of commercialization. While transaction costs may or may not be higher vis-à-vis vertically integrated firms whose resources are maintained internally, the new institution could enable faster and more effective solutions to problems.

Firms have also responded to increased competition amid scarce resources. For example, DBFs are narrowing their focus to single therapeutic areas or technology platforms with wide-ranging applications rather than trying to be "all things to all people."[68] Some advocate licensing non-core NCEs, key assets of most DBFs, in order to secure short-term revenue that in turn could support long-term development of core assets that will gain a higher return. Start-ups are establishing alliance networks – both upstream and downstream – at founding rather than later in their evolution and configure them to reduce costs, duplication and complexity (Baum, Calabrese, & Silverman, 2000). Firms are beginning to ally with established rivals in order to learn, but ensure that partners in the network do not compete among each other (Baum et al., 2000). Some firms establish as "virtual companies" with headquarters in Montreal, researchers in Boston and suppliers in Asia. While others, like Bellus Health managed by Roberto Bellini, the son of Francesco Bellini founder of BioChemPharma, Quebec's biggest success, no longer focus on R&D, but repurposed drugs and therapies that provide faster returns.

VC strategies have also changed how they are organized, governed and invest. There are several types including privately held and managed, publicly financed but privately managed, big pharma-funded and managed VCs like GSK and Pfizer, and "fund of funds" like Teralys Capital. Teralys manages financing from other VCs, some public

[68]Author interview, Montreal, Canada, October 2012.

others private, and invests in target sectors like clean technology, life sciences and information communications technology.

However, VCs faced certain challenges during 2007-2012. It is now more difficult to syndicate opportunities among investors. The costs of producing drugs are increasing so there is a need for good quality management and assets like NCEs. The typical goal now for VCs is to focus on the lowest "spend," about 3-5 year investments, in return for the highest growth, or "early investment, early returns."[69] For example, VCs like TVM invest in pre-indication through to phase II or pre-clinical to technical proof of concept in humans for new drugs. Afterwards, they sell to strategic partners, typically a large pharmaceutical firm. In the past, VCs would invest in either later stages of drug development, closer to commercialization, or along the entire value chain. VCs now are increasingly searching internationally for partners and investments whereas during the 1980s and 1990s, they focused domestically.[70]

Government backed VC funds like those managed by the Business Development Bank of Canada (BDC) take on a holistic approach to investing in bioscience products and technologies. These VCs operate under a different set of objectives, namely economic development and better healthcare, including drugs, for Canadians. BDC invests longer term and in a wider range of firms. However, BDC is criticized by private sector VCs and biotechnology firms for not having the requisite skills and knowledge to conduct due diligence on investment opportunities particularly since BDC originated as a traditional commercial bank.

Large pharmaceutical firms are also reorganizing to balance risk and return through both competition and cooperation. Many like Pfizer and GSK are outsourcing R&D through partnerships with DBFs yet they also continue research collaboration with universities. In addition, large pharmaceutical firms are simultaneously establishing their own VC funds and co-investing with competitors as a limited partner particularly since financing and good investment opportunities are increasingly difficult to find and vet alone. Furthermore, pharmaceutical firms are redesigning their VC fund strategies to

[69] Author interview, Quebec City, Quebec, October, 2012.
[70] Author interview, Quebec City, Quebec, October 2012.

invest in “cures” versus “treatments.”[71] Finally, pharmaceutical firms are diversifying their products by investing not just in biopharmaceuticals, but medical technologies.

Changes have also occurred at the individual entrepreneur level. Individual successful entrepreneurs who have gained credibility within the industry are increasingly mobilizing industry in strategic ways whereas in the past they did not. For example, these entrepreneurs have formed working groups comprised of representatives of all bioscience application areas, niches and firm types on the basis that. One interviewee spoke for many:

> It is critical to get everyone on same page, then industry can attract government investment. Now, we must have more innovative leveraging from big pharma R&D budgets, government funds, and university research without which we would not have gotten more funding. This is a public goods argument. Pharma is not going to fund it alone, therefore industry needs government. We all need each other and need to involve everyone.[72]

In addition, the strategy should not involve picking winners, but focus on niches like personalized medicine. DBFs are beginning to focus their corporate strategies on developing one-two NCEs and dropping the rest. The thinking is, “Start with what you’ve got, and if not much, then you have to be laser-focused on your niche if you want to attract companies like Novartis. Then, you can interest government in it.”[73]

Regional bioscience stakeholders, sometimes led by government and sometimes by industry, began to establish new institutions based on public-private partnership (PPP) models. These are designed to create incentives for participants to share information and resources to save on rising costs of pursuing these tasks alone. In return, bioscience organizations would receive sufficient benefits including access to the research and technologies.

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[71] VC panel presentations, BioContact in Quebec City, Quebec, 2013.
[72] Author interview, Quebec City, Quebec, October 2012.
[73] Ibid.

For example, in 2008 the federal and Quebec government and large pharmaceutical firms like Merck and Novartis invested C$4 million and C$1 million each, respectively, in a new research institution, the Québec Consortium for Drug Discovery (CQDM). This is a pre-competitive consortium designed to facilitate a faster drug development process in partnership with the pharmaceutical industry. In 2012 the Quebec government, AstraZeneca and Pfizer established a non-profit research institute called the Neomed Institute designed to bridge the gap between academic research and industry by funding collaborations with universities and biotechnology start-ups. Both are attempts to make up for large pharmaceutical firms closing down their R&D and manufacturing centers in Quebec over the last five years.

Governance mechanisms include a board of directors comprised of industry, academia and government. This new collaboration model claims that it is a "network of exchange and cooperation" in research among universities, hospitals, biotech firms and the pharmaceutical industry. Public and private sector partners design collaborative projects and share in results rather than just responding to request for proposals (RFPs).[74] This type of collaboration represents a level of embeddedness and coordination not achieved by markets alone. However, it is too early to determine its level of effectiveness.

Institutional Configuration: Balancing Coordination and Competition

While Quebec's bioscience cluster contracted after years of growth, the strategy community created new and transformed existing institutions. The new institutions are designed to solve certain problems inherent in this science-based industry. These include, lack of information and knowledge-sharing, and, uncoordinated financing mechanisms needed to take discoveries from the lab to market. The key problem was how to reduce the costs of innovation and cluster development while securing higher return on R&D investments.

[74] See:http://www.cqdm.org/en/cqdm/business-model.php

Below I examine a representative sample of new and changed institutions as well as modes of coordination around finance, skills, product markets and knowledge. These include: the globally networked region; interregional alliances; reorganization of provincial government ministries; project-focused companies (PFCs); small biotechnology firm strategies designed to create focus, flexibility and coordination; large pharmaceutical companies outsourcing R&D to small biotechs and universities while creating their own VCs; VC reorganization; and public-private partnerships.

Provincial Institutions

Bioscience industry, university and government stakeholders increasingly attached importance to the role of global networks in research, finance and skill development. The region is forming R&D and financial networks that are becoming more disease-specific and therapy-focused, combining "global expertise with a local response."[75] For example, Quebec and the state of California each are contributing $60 million to a cancer research project focusing on stem cells.[76] An individual entrepreneur in California, Robert Klein, led the effort to commit California's legislature to issue state bonds for stem cell R&D, in direct opposition against U.S. national policy on stem cells. California's strategy brings the role of global R&D and financial networks to the center of drug R&D. In turn, Quebec's efforts to forge ties separately from Canada's federal agencies provides evidence for the relative autonomy that Canada's regions have in designing and implementing knowledge-based industrial strategies.

Canadian provinces are coordinating among themselves in order to gain efficiencies particularly in translating R&D spending into higher product and technology commercialization rates. For example, In 2005 Ontario founded a public-private partnership, Medical and Related Sciences (MaRS) facility that would reduce knowledge silos, "nurture a culture of innovation … and help create global enterprises that would

[75] Author Interview, Quebec City, Quebec, October, 2012.
[76] Public Presentation by Klein Financial, BioContact in Quebec City, October 2013.

contribute to Canada's economic and social development."[77] Quebec now partners with MaRS in order to share information, contacts and resources since Ontario's bioscience success has rested more on the private sector. MaRS acts as a bridging tie between the two networks, provinces and their bioscience communities.

By 2012, Quebec's new Premier combined the Ministry of Finance, Ministry of Tourism and the Ministry of Economic Development, Innovation and Export Trade (MDEIE) to form a new institution, the Ministry of Finance and Economy. This change reflects a political interest in establishing new organizational forms conducive to implementing the new government's economic and finance programs. The overall mission, however, remains the same: facilitating finance, economic growth and tourism. Separately, Quebec's Ministry of International Relations of la Francophonie and International Trade will oversee the province's export strategy that the former MDEIE used to manage, while the new Ministry of Higher Education, Research, Science and Technology is responsible for research and innovation.[78]

The MDEIE's and Office of the Chief Scientist's mobilization of smaller, distributed knowledge-oriented strategy teams into a province-wide network strengthened Quebec's high commitment to bioscience after the GFC. This team negotiated not only their own strategies but a new provincial one. Revised overarching goals included "mobilization, innovation and prosper" (MDEIE, 2010). This approach coupled with individual firm strategies and a favorable business environment is designed to restart industry growth.

The major strategic change during this period was to emphasize equally wealth creation along with support for the healthcare system. To do so, stakeholders support government procurement of local innovations, multi-stakeholder partnerships particularly at pre-competitive stages of product development, more effective risk management by learning how to segment different types of risk along the drug development chain, and local-global collaborations. This focus on mobilization and coordination of resources and

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[77] See:http://www.marsdd.com/aboutmars/story/

[78] See: http://www.economie.gouv.qc.ca/ministere/english/about-us/creation-of-the-ministere-des-finances-et-de-leconomie/

the goal of promoting Quebec as a global biopharmaceutical hub is largely in response to the 2008 financial crisis.

4.3.1.3 Ontario: Fragmentation and Path Dependence?

Ontario maintained a mixed commitment to bioscience after the GFC. The Ontario government designed an innovation policy to improve the business environment by increasing R&D financing, tax incentives for both research and training, building infrastructure, and creating government funded, privately managed VCs similar to Quebec. Biotechnology firms shed non-core assets and developed some alliances to remain viable. Industry associations addressed the financing gap by creating new seed funding mechanisms. Despite these incremental changes there was no overall strategy to strengthen and adapt linkages among finance, skill development and firm competencies to new circumstances.

There is no evidence of a strong KOST and little indication that policy communities developed a shared mindset and coordinated around common goals. For example two industry associations, the incumbent Life Sciences Ontario and the newly established Ontario Bioscience Innovation Organization, fought for resources and relevance rather than “speaking with a common voice”. However, individual policy communities often represented by a formal organization like an industry association continued to learn. They evaluated industry goals and previous strategies, gathered lessons learned from similar jurisdictions, and created new individual strategies.

Ontario remained trapped in old ways of organizing its economy that are less conducive to science-based industry development despite learning gains. Multiple policy communities with competing interests, a lack of shared strategic goals, rival industries vying for resources and a history of market-led industrial development help explain this mixed strategy.

The difference between Quebec and Ontario lies in just how far government embeds itself in strategy development and implementation. While both invest in PRO, university and hospital R&D, Quebec creates sector plans co-designed with and implemented by the private sector. Quebec demonstrated its high commitment to R&D by establishing in

2011 an Office of the Chief Scientist. Ontario, on the other hand, creates a favorable business environment in the hopes of growing local firms and attracting FDI but industry does not speak with one voice. Individual firm strategies collectively reflect industry development.

By 2009 and for the first time in its history Ontario became a "have not" province. Ontario's industrial decline particularly in its automotive and manufacturing industries began years before the GFC. But the GFC exacerbated the situation calling for creative responses.[79]

In 2008 the province negotiated an Innovation Agenda with a local-global connection in order to address economic decline. It singles out the primary challenge of translating research into commercializable products and services. The strategy is designed to attract entrepreneurs, innovators and FDI from overseas; invest in, generate and attract a highly skilled workforce in science, engineering, creative arts, business and entrepreneurship; stimulate private sector investment in knowledge-based firms; improve productivity and promote a supportive business environment in Ontario abroad. In 2010 the province created a bioscience strategy in support of the new agenda (OMRI, 2010).

Ontario's bioscience industry contracted from 118 to 98 biotechnology firms between 2006 and 2007 and continued to decrease after the financial crisis (E&Y, 2008).[80] However, the province promotes itself as the fourth largest biomedical research center in North America and a life sciences hub. On the surface the data supports this view. 20 universities and 24 colleges developing curricula jointly with industry and graduating 9,300 students in science and engineering fields annually; 60 public research organizations including the Ontario Institute for Cancer Research; several biopharmaceutical MNCs such as Sanofi Pasteur, Roche, and Johnson & Johnson along

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[79] During 2009-2010 the province collected $347 million from the federal government under Canada's equalization payments system to help offset shortfalls in taxes to support basic government services. Quebec was to receive $8.35 billion. Newfoundland and Labrador, one of Canada's poorest provinces, no longer receives equalization payments after becoming a "have" province with the discovery of offshore oil and gas. See:http://www.cbc.ca/news/canada/ontario-to-receive-347m-in-equalization-flaherty-1.766492

[80] Ontario's life science's strategy reports 140 firms in 2009, however, these numbers are hotly debated among industry organizations and the province. OBIO is calling for a more standardized method of capturing biotechnology firm data, separating pharmaceutical and health services organizations from the small biotechnology firms.

with successful local firms Apotex and Biovail; 40,000 employees at 850 companies (representing all bioscience firms, not just biotechnology); and revenues of $15 billion. $5 billion dollars is derived from exports. The province promotes its expertise in genomics, neuroscience, oncology, cardiovascular disease and clinical trials (MRI, 2010).

These impressive statistics do not represent the prevailing local attitude among industry that weaknesses persist. There are very few local start-ups, anchor companies and much needed medium-sized biotechnology firms to attract significant FDI. Those MNCs in Ontario are not investing in local industry nor are small and medium-sized firms receiving much support.[81]

Industry and some in government agencies claim that the province has no strategy and still relies on a "cultural preference for university research" as opposed to public-private partnerships to drive commercialization.[82] Those firms that are selling products are selling them either to the provincial healthcare system or internationally. This structure that is tied to the healthcare system actually reduces incentives to invest in R&D to innovate and does not create a need for strategy. The disconnection between government and industry is underpinned by old institutions separating them in support of traditional industries like plastics and transportation.

Four events characterize this period in Ontario. First, the province developed a new innovation strategy similar to the federal government embracing the role of technological innovation in sustaining Ontario's economic competitiveness. Second, the MRI produced its life sciences strategy in support of the same goals outlined in the broader innovation agenda. But there are claims that no strategy exists leading to the possibility that it is not actually being implemented nor was it negotiated in a coordinated manner involving key stakeholders.[83] Third, government created new financial institutions in the form of government-backed, privately managed VC funds. Ontario learned from Quebec about the benefits of these public-private partnerships despite the province's failed attempts to outsource management of innovation projects in the 1990s and early 2000s. It breaks with

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[81] Author interview, Toronto, Ontario, March 25, 2014
[82] Author interview, Toronto, Ontario, March 24, 2014
[83] Author interview, Toronto, Ontario, March 24, 2014

Ontario's traditional preference for privately held and managed funds. Fourth, industry remains fragmented. Two associations compete to be the voice of industry despite formalization and coordination of industry segments *within* each organization.

Provincial Government Commitment Strategy

By 2010 the province began implementing changes in ministries reflecting new roles aligned with new overarching goals, but the changes created uncertainty around the priority level that the province assigns to research and innovation. For example, the Ministry of Health and Long-Term Care (MHLTC) changed its mission from actual delivery of health care to "stewardship" in planning and guiding resources to "bring value to the health system."[84] Historically this ministry financed R&D in health technologies as well as delivered healthcare to Canadians. But over time the Ministry of Research and Innovation (MRI) took on the R&D financing responsibility linking research to innovation.

In 2011 the provincial government folded the MRI, founded in 2005 in support of research and commercialization of new technologies, into the Ministry of Economic Development, Employment and Infrastructure (MEDEI). This change more closely linked research and innovation with competitiveness and high wage, higher skilled jobs.[85] It also established mechanisms to connect local Ontario scientists with those in the strategic markets of China, India and Israel.[86]

The approach is very different from experiments in the 1990s that favored public-private partnerships, contracting out through a sole-source agreement management of the province's research and innovation agenda and budget of $1.25 billion to a private corporation, the Innovation Institute of Ontario (IIO). It was discovered that IIO did not develop a clear strategy to meet the objectives of promoting innovation, economic growth, and job creation. By 2013, MRI became a separate ministry again with a budget

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[84] See: http://www.health.gov.on.ca/en/
[85] See: https://www.ontario.ca/government/about-ministry-research-and-innovation
[86] See: http://www.ontario.ca/business-and-economy/international-research-projects-china-india-israel

of $911 million. The new VCs funds and management partnerships analyzed below are financed by MRI and housed within this ministry. Getting it right when it comes to public-private partnerships is not guaranteed in the initial design. A purely functionalist explanation does not support this outcome as the implementation process produced unforeseen outcomes.

Ontario's MRI responded in 2010 to tight credit markets, increased competition from emerging markets and the province's previous unsuccessful attempts to transition to a knowledge-based economy with a formal bioscience strategy, "Ontario's Life Sciences Commercialization Strategy." The strategy supports the province's broader Ontario Innovation Agenda and Open Ontario, a five year plan to create jobs and growth in Ontario and to position the province as a prime location for knowledge workers. It also stresses a comprehensive approach to distinguish itself in a dense, globally competitive environment (MRI, 2010).

Similar to Quebec and federal policies, the $161 million strategy sought to promote greater collaboration among government, academia and industry; attract more MNCs/FDI particularly advanced health technologies firms to buy or test new therapies in Ontario; and grow the local biotechnology industry to compete against US and global bioscience clusters. To do so the province seeks to fill the skills gap by attracting and producing leading scientists, facilitate greater collaboration, address the finance challenges and increase the Ontario brand globally (MRI, 2010).

However, strategy implementation is as important as its initial design in creating high levels of commitment. For example, in Ontario the prevailing norm when it comes to searching for and attracting FDI to redress the decreasing manufacturing base is to continue to attract large manufacturing firms that can provide a significant number of jobs.[87] This model is less effective in the bioscience industry, which is heavily reliant on small biotechnology start-ups with the potential to grow. This short-term thinking by government technocrats is incompatible with the long-term nature of the biotechnology industry.

[87] Author interview, Toronto, Ontario, March 25, 2014.

The research community supports this focus on greater coordination and breaking down of silos to unleash new tacit and formal knowledge. But certain institutes ground the approach to a particular scientific area like genomics. Dr. Mark Pznansky, President and CEO of Ontario Genomics Institute states that:

> We lack not the capacity, but the ability to connect new knowledge to the needs of industry and financial resources…Genomics is the foundation of what we're calling the future bio-economy in Canada, which involves all of this nation's economic activity that results from the life sciences. (MediaPlanet, 2013, p. 2)

Furthermore, he becomes more specific when elaborating the nature of the coordinative approach indicating that the province needs:

> A holistic finance system where government (through proof-of-concept grants), industry (through true academia/industry partnerships) and venture capital all participate to support the passage of a product through the development pipeline; strong regulatory and public policy as well as an efficient tax system that provides incentives for companies to thrive in Ontario, and procurement policies where, in a reasonable way, a "Buy Ontario" culture is promoted. (MediaPlanet, 2013, p. 2)

This approach emphasizes coordination to generate new knowledge and gain value from investments as well as globalizing the province through FDI and knowledge worker attraction strategies.

Industry was learning at the same time when provincial ministries and public research organizations were shaping a new bioscience strategy. Industry created new and changed existing institutional organizations. But while the social learning process was disruptive, it took place when political bargaining was highly fragmented.

Industry Strategy and Institutional Change

Unlike Quebec, Ontario contains two very different bioscience associations, the Life Sciences Ontario (LSO) and the Ontario Biotechnology Industry Organization (OBIO), each claiming to represent industry. The LSO is the incumbent industry association founded in 1989 but renamed the Toronto Biotechnology Initiative in 2010 reflecting a geographically expanding membership. 150 organizations from medical technologies and agri-food to biochemicals, service providers and universities are now members. The organization's main goal is to promote commercialization throughout the diverse life sciences sector.[88] To establish its legitimacy and role vis-a-vis industry and all levels of government LSO claims "Diversity of Members, Unity of Voice."[89]

This diversity of membership is coupled with the association's goal to break silos and improve learning:

> Everything at LSO involves incorporating different sectors of life science. LSO is trying to create a learning opportunity for the different sectors to allow them to learn from each other. Maybe the human health sector can learn from the agricultural sector in terms of entrepreneurship. LSO is trying to create cross-fertilization. The association determined that process of integrating across the life sciences at an early stage. The vision is there, and we see how the technology can be applied, but we still have a long way to go.[90]

In 2013 LSO collaborated with Quebec's industry association, Biopolis Quebec, to produce two joint position papers for the federal government. Like OBIO, this industry association also educates policymakers on Ontario's life sciences industry and its economic and social impacts (LSO, 2013).

This positioning contrasts with OBIO. OBIO was founded in 2008 immediately after the global financial crisis when small and medium-sized (SME) biotech firms began to search for government financing as they struggled to survive. OBIO established itself in

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[88] See:http://www.lifesciencesontario.ca/about/aboutLSO/index.php
[89] See: http://www.lifesciencesontario.ca/about/history/index.php
[90] Author interview, Toronto, Ontario, March 27, 2014.

response to TBI at the time, which was perceived to be an "older institution that did not keep up" with industry needs especially SMEs.[91] While LSO's mission is to be a community organization and all-encompassing in terms of membership and bioscience areas, OBIO is sharply focused on health technologies and SME growth. But it does rely on the membership of large pharmaceutical firms and government agencies.

Furthermore, each association frames the challenge differently, has developed its own strategies, governance structures and working groups, taking lessons learned in the case of OBIO from jurisdictions as far as Victoria, Australia and Israel to see which institutions may translate effectively to the Ontario context (OBEST, 2011). OBIO's overall goal is to help build Ontario's bioscience cluster into one that is producing innovative products and services and selling them globally, rather than just to the local Ontario market through its formulary. Another goal is to create industry stability and to reverse the trend of Ontario bioscience firms developing IP in Ontario, selling it overseas only to purchase final products at a higher cost. The Executive Director of OBIO captures this process:

> Ontarians do not reap the benefits of an innovation economy due to the underdevelopment of the biosciences industry sector. Our investments in research, novel commercial technologies, highly-qualified individuals, and smaller start-up corporations are, for the most part, lost to foreign markets. The commercial products and services developed from our innovations are then bought back by Ontarians (in the form of novel therapeutics, diagnostics, and devices) at considerable mark-up. The increased costs are not only a growing burden for tax payers, but more importantly, we as Ontarians have not benefited from the economic prosperity (jobs and wealth creation) that would result from a strong and sustainable domestic biosciences sector. (OBEST, 2011, p. 3)

Furthermore, OBIO defines the problem in two ways. First, it is one of managing healthcare costs by enacting fundamental policy reforms to support innovation and

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[91]Author interview, Toronto, Ontario, March 25, 2014.

growth. Second, the association is reacting to previous policies and experiences. It argues the need to rely less on commodities and extraction industries to finance and sustain the healthcare system and to make a higher commitment to a knowledge economy. The way forward lies in social learning and a more collaborative process, “in identifying and correcting past mistakes, adjusting conventional wisdom that has led us astray, learning from international best practices and adopting a collaborative approach to create made in Ontario solutions” (OBIO, 2012, p. 3).

In 2011 OBIO created the Ontario Bioscience Economic Strategy Team (OBEST) to design and implement its plan. It was comprised of “…all stakeholders in the Ontario bioscience community who want to create the conditions for sustainable growth of Ontario’s bioscience industry” (OBEST, 2011, p. 2). The six month planning process involved the creation of subcommittees with specific roles and tasks including the creation nine work plans in support of defined goals.

Industry led the creation of five plans and was specifically charged with defining the industry’s priorities, raising awareness of its potential, creating SME networks, and building and attracting “patient” capital. Government-industry partnerships address the other four including: identifying and investing in Ontario’s health priorities; clearly showing integrity of process; using the province’s procurement process to create and drive markets; and changing government incentives in favor of industry. Implicit in government’s responsibilities is the assumption that its policy-making fails to include industry input in a fair and transparent fashion. This particular strategy reveals that two implementation tactics: industry-led and government-partnered implementation.

Both associations are reacting not only to external forces but also to previous industrial policies and institutions that have not kept up with the pace of change. Yet, the politics of incumbent versus new institutions fragment the process and force the two associations to compete to be industry’s voice.

Table 10 Finance, Skill Development and Corporate Governance

	Finance	Skill Development	Corporate Governance
1st Order – Settings	**Biotech R&D spending (US$); R&D tax credit changes**	**Tax Credits – Scientists, Technical specialists**	**Make or Buy Decision – Amount of R&D in-house**
2007/2012 (pre/post financial crisis)	After 2007 – Companies can acquire the rights to IP developed at PROs (similar to Bayh-Dole). 2010 –Province invests - $500 million annually in basic& translational life sciences R&D. 2014 –$14.6B R&D spending total among all LS groups - biz, gov, hospitals etc. 2010, no more capital tax on Ontario businesses 2011 – OBIO proposal to modify gov't funding programs to enable *rapid* access to and deployment of gov't funding.	2008 – 72.8% firms provide training to staff but by 2013, only 64.7% of firms did. 2004 - Apprenticeship Training Tax Credit enhanced by 2009 – amount of claim doubled ($5k – 10k), training time increased from 3 to 4 years, program went from temporary to permanent.	Increasingly external Mirrors national changes After 2007 -Ontario Tax Exemption for Commercialization (OTEC) – new companies.
2nd Order – Techniques	**Diversification of finance sources**	**Program Changes**	**Diversity of R&D models**
2007/2012 (pre/post financial crisis)	New gov't VC & research funds: OVCF, NVCF and OETF; fewer private VCs and institutional investors; no IPO market; more gov't VC funds to BDC --OBIO – Capital Access Advisory Program (building SME capacity)	-Focus on developing and recruiting entrepreneurs, experienced managers -Build infrastructure to attract scientists: Ontario Research Fund; $114 million Global Leadership Round in Genomic & Life Sciences -Foster scientific talent at the earliest stage – youth mentoring opportunities	-Still focus on M&A as scenario for success -Co-development/partnerships
3rd Order – Overarching Goals (Paradigm change)	**Core focus shifting (e.g. basic-commercial research, niche application areas, niche science areas**	**Core focus shifting**	**Core R&D strategy shifting**
2007/2012 (pre/post financial crisis)	Genomics/health focus competing with broad-based agri-food tech, environmental; little change in overarching goals by government, but industry taken the lead.	-Greater collaboration -Internationalization of networks -Greater Interdisciplinarity	-Coordination; Integration -VCs like TVM investing more in individual molecules rather than companies.

Sources: BioTalent; Ernst and Young; PricewaterhouseCoopers; OBIO; http://www.investinontario.com/life-sciences ;

Did finance institutions change after the 2008 global financial crisis?

Different policy communities made incremental changes to both levels and types of bioscience finance one year after the GFC. The changes represent a mixed level of commitment. Even though government has stepped in to fill some financing gaps left by private sector sources leaving, these are not strategic responses with overarching goals attached.

The province increased support for health biotechnology with an emphasis on genomics that competed with rival industries in agri-food and environmental technologies. Many private VCs and other sources of funds folded at the time. The province began to fill this gap by establishing two VC funds, the $205 million Ontario Venture Capital Fund LP (OVCF) and the Northleaf Venture Catalyst Fund LG (NVCF) jointly with the federal agency, Industry Canada.

The OVCF invests *mostly* in "Ontario-based and Ontario-focused venture capital and growth equity funds that support innovative, high growth companies."[92] This rule contrasts with Quebec's whose funds traditionally have been tied to investment in Quebec firms only. But industry prefers untied funding. Quebec is crafting a similar argument now especially when there are fewer opportunities yet intense competitive for profitable investments globally. The Ontario Capital Growth Corporation (OCGC) was established in February 27, 2009 in order to manage the limited partner interests of the government in the two VC funds. To ensure well-informed investment decisions OCGS contracted two private sector specialists, Covington Capital Corporation and Ernst & Young to evaluate applications, administer and monitor co-investments.[93]

In 2009 the province created the $250 million co-investment fund, Ontario Emerging Technologies Fund (OETF), to be managed and operated also by OCGS. This fund, similar to the VC funds in Quebec formed earlier in the decade, target three knowledge-based industries: clean technology; life sciences and health technologies; and digital media and ICT. It invests directly in Ontario-based firms in these sectors needing to raise

[92] See http://www.ovcf.com/AboutOVCF/InvestmentStrategyObjectives/tabid/59/Default.aspx
[93] See http://www.ocgc.gov.on.ca/index_en.php?page=ontario-emerging-technologies-fund

VC and other risk capital. The fund is designed to achieve both government goals of investing in sectors of strategic importance to the province and in catalyzing private sector capital as well as investor goals of profitably investing in knowledge-based growth companies.

The province is attempting to apply both public and private sector capabilities towards financial vehicles designed to reach both firm-level corporate growth goals as well as provincial economic development goals. The mechanism also offers an opportunity for social learning. These changes represent a shift in paradigm concerning the role of the province in leveraging and investing in new technologies and firms. Previously, primarily private sector VCs invested in high growth firms and there were a number of these VCs operating in Ontario in the early 2000s. However, during the 2008-2013 period the number of purely private life sciences VC firms has decreased to about three or four with Lumira and Genesis Capital as leaders.[94] Searching for alternatives, Ontario began much later than Quebec in establishing public-private VCs.

In addition to the VC funds, the province established the Ontario Research Fund Advisory Board (ORFAB) to review, assess and make recommendations to the Minister to fund promising basic research applications and the Early Researcher Award. The board is comprised of nine advisors eight of which come from universities representing mostly natural sciences and engineering with one social scientist. The board meets six to eight times per year to speed project approvals. There are no industry representatives except one who straddled both the public and private sectors.[95]

The configuration of the board indicates that industry has little input, at least through these mechanisms, into shaping research agendas, which reflects Ontario's as well as Quebec's culture of R&D as university R&D not necessarily industry-led. The board provides strategic advice to the Minister on the research agenda in support of Ontario's competitiveness goals. The new VC funds are designed to catalyze industry through direct firm investments while the research funds are directed towards the universities.

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[94] Author interview, Quebec City, Quebec, October, 2012.

[95] See: http://www.pas.gov.on.ca/scripts/en/bios.asp?minID=3220&boardID=141262&persID=149235#1

In addition to the above changes to conventional sources of funding, government and industry are designing completely new types in order to give small start-ups a competitive advantage and to prevent them from moving to the U.S. where there are more diverse sources of financing. For example, equity-based crowdfunding is of growing interest in both Ontario and Quebec. But with new governments come changes. Premier McGinty tried to pass legislation creating an angel investor tax credit similar to the highly successful rules in British Columbia but the legislation failed after losing the election. The ultimate goal from industry's perspective is to support a growing diversity of capital to facilitate bioscience firms at all stages of the value chain.

Did skill development institutions change after the 2008 global financial crisis?

Enhancements were made to provincial tax credit programs in response to data indicating that firms were investing less in staff training programs during this time. Changes to programs were made to attract overseas scientists and to build infrastructure. These included the Ontario Research Fund and the $114 million Global Leadership Round in Genomics and Life Sciences. To cultivate local scientific talent at earlier stages, the government established youth mentoring programs, which paired young students with established scientists.

The nature of skills required for bioscience during the period shifted from a demand for senior scientists to a need for technicians, business developers and experienced managers. BioTalent Canada reported that the top three critical skills demanded by all types and sizes of firms were interpersonal skills, business development and management/leadership skills. While the size of the skills gap in 2008 did not change substantially by 2013 with the percentage of firms reporting a skills shortage reaching 33.2 and 34.4, respectively, the nature of skills required did.[96] But firms were not able to offer as much training to employees largely because of scarce financing.

The data indicates strong institutional complementarity between skill development and finance. To solve this problem, Ontario's provincial strategy involves improving the

[96] See: http://www.biotalent.ca/bio-economy-facts

institutional environment to attract non-local scientists and provide training programs and incentives for local talent. Third order changes in overarching goals have been made in focusing on greater collaboration, internationalization and interdisciplinarity. Previous efforts focused primarily on university R&D and individual firm programs as skill development mechanisms. Here the shifting roles of the public and private sectors are evident in that government increased support for skills development in new areas while the private sector decreased support.

Did corporate governance institutions change after the 2008 global financial crisis?

Competing policy communities led to mixed levels of commitment to building corporate competencies after the GFC. Government agencies encouraged Ontario firms to co-partner on R&D projects with local firms and MNCs to generate knowledge spillovers with the hopes of growing the industry locally. Big pharmaceutical firms were demanding that small biotechnology companies develop core capabilities in one or two areas rather than several. This strategy would prepare them for a merger or acquisition and increase the probably of relocation.

The sale of local start-up, ARIUS, to Roche Pharmaceuticals in 2008 should have signaled opportunity for other small biotechnology firms and the province as a whole. However, as the financial crisis worsened other small firms found it difficult to secure enough private sector financing to continue R&D. As in many other jurisdictions, these firms began to look to government for risk finance. Yet in Ontario up until this time little existed as most R&D funding was distributed to university.

Building competence and confronting the “make or buy” decision, in Ontario those firms that had at least survived the 2008 financial crisis were searching not only for government risk financing, but also co-development partnerships with larger pharmaceutical firms and other small biotechnology companies. Increasingly, merging with or being acquired by another firm is seen as a form of success.

This strategy, however, competes with the industry association’s goal as well as the provincial government’s whose interests lie in keeping local firms and growing them to meet employment and industry stability goals. Creatively reconciling these differences is the challenge. There does appear to be a growing acceptance that some local firms will develop assets and sell as an exit strategy but that the province also needs large firms that stay.[97] One interviewee referred to Nortel as an example of a large firm that created a number of smaller suppliers and partners. While Nortel was bankrupted in 2013, it is argued that it was better to have this global firm in Ontario than not.[98]

In addition to biotechnology firms, the VCs such as TVM are investing more now in small molecules rather than companies themselves. This approach reduces costs and focuses investments on the specific asset and gives the VC flexibility in managing the process especially in securing resources and meeting deadlines. However, this "project-focused company," similar to what we observe in Quebec, may increase transaction costs as the complexity of the process requires regular monitoring and learning.

Conclusions

Ontario maintained its mixed commitments to bioscience after the 2008 global financial crisis. New policy communities represented conflicting interests that have yet to be resolved. Government-industry relations in Ontario are based on traditional norms that largely separate and confine roles and responsibilities.

Governments typically react to industry needs only when industry approaches them. While previous experiments with Sector Strategies in the 1990s and more recently with the Life Sciences Strategy represent attempts at learning how to learn, and a recognition that new modes of public-private sector relations can be valuable, the province has little experience sustaining such approaches. Furthermore, the perception from industry is that there is a "zero-sum" attitude still among government, industry and universities rather than positive-sum relationships needed for industries such as biotechnology. Unlike most industries, bioscience firms in Ontario are demanding a stronger government role in helping to fill the financing and skills gap as well as creating a supportive business

[97] Author interview, Toronto, Ontario, March 27, 2014.
[98] Ibid.

environment. But actors are still trying to figure out who takes on what roles and responsibilities.

Understanding the complexity and changing nature of roles and relationships among the triple helix of industry, government and universities is a challenge faced by each stakeholder group. For example, despite the many institutional changes in the area of provincial risk finance and in some tax credit schemes, the perception is that government lacks the knowledge and political will to support industry as it relies on old norms that defined R&D investment as investing solely university R&D, not industry. One interviewee highlighted the difference between Ontario and a leading biotechnology cluster, Boston, MA. In Massachusetts, the state's economic development agency manages a $1 billion life sciences fund while the Governor clearly states that it is the role of the state to help start-ups evolve and de-risk so that they attract investment (MBT, 2009).[99] In Ontario, it is not clear that the province makes such a commitment. This is partly an issue of how the life sciences industry is viewed, more as a cost to the healthcare system rather than an investment in technological innovation as a driver of economic development and ultimately economic contributor.[100]

During this period industry structure was fragmented along both functional lines and diverging interests. Further exacerbating the problem is the competition between two industry voices, LSO and OBIO, with neither institutional organization able to coordinate these interests and negotiate with government. Industry understands that no single change in rules will successfully alter Ontario's path dependent trajectory towards fragmentation. While there is talk of coordinating stakeholder interests around shared goals such as generating and attracting continuous risk finance, skilled workers in specific science and engineering disciplines as well as service areas, and more medium-sized bioscience firms strong enough to attract potential FDI as anchors, the approaches are fragmented.

One interviewee noted that Ontario does have an industrial success story from which it can learn.[101] Sixty years ago the province identified natural resources as a source of

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[99] Author interview, Toronto, Ontario, March 27, 2014. See also http://pbn.com/Patrick-unveils-10-year-1B-planbr-to-boost-life-sciences-in-Mass,25316?print=1

[100] Author interview, Toronto, Ontario, March 27, 2014.

[101] Ibid.

economic potential. It was underfunded but represented high risk similar to biotechnology. After a period of providing R&D tax credits the province paved the way for firms to list on the Toronto Stock Exchange, which is currently the largest exchange in the world for natural resources. This lesson learned is used as part of an argument for creatively designing similar structures for today's high-risk industries like biotechnology. Despite the impressive number of firms, employees and discoveries as well as globally recognized bioscience research infrastructure and institutional changes during this period, government, industry and universities have not yet combined disruptive social learning with coordinated bargaining processes. Having said this, through regular briefings and annual public conferences, industry is taking the lead and beginning to educate both elected officials and technocrats on the nature of the bioscience industry and its potential impact on economic development goals.

4.4 Conclusions

4.4.1 Empirical Findings

Traditional industries underpin Quebec's and Ontario's economies as they struggle to reinvent themselves towards knowledge-based economies. Even though both contain large biomedical research facilities, invest significant amounts in R&D and are home to biotech and pharmaceutical organizations, they maintain different commitment levels toward bioscience.

Quebec built social learning structures including a strong KOST *prior to* the financial crisis that helped the province adjust and maintain its high commitment. Ontario's legacy of neoliberal economic approaches, while successful in other industries, is less suited to the needs of biotechnology within the context of rapid innovation, increased scientific complexity, scarce financial and human resources. The province maintained a mixed commitment to bioscience as multiple policy communities fought for resources and legitimacy.

Quebec and Ontario share several themes. First, they struggled to fill the skills and finance gaps. Second, provinces and their industries emphasize increased collaboration between private firms and between firms and public research organizations through joint projects. Both argue that governance mechanisms must embrace coordination to manage the increased complexity of science and industry. The commitment requires greater industry - government social learning about problems, potential solutions, industry trends and processes. It also requires greater integration of organizations and approaches. But in Ontario it is difficult to overcome cultural norms against public-private sector coordination. In Quebec the approach fits well with cultural traditions even though coordinated negotiations can still involve conflicting interests.

In finance both acknowledge the need for more diversified sources to fill gaps along the entire product development value chain. Instead of just government grants and some VC funding, the provinces advocate expanding angel and big pharmaceutical firm investments as well as and a stronger stock exchange. Quebec invested first in government-backed, privately managed VC firms. Ontario did so only recently and just after the global financial crisis whereas in the past the province relied solely on privately funded and managed VCs.

In skill development both provinces support an interdisciplinary approach toward R&D projects and university degree programs to solve the most complex yet potential high reward problems. Both provinces also cite the need for entrepreneurs, skilled managers and business development staff.

Corporate governance in both provinces has changed whereby small biotechnology firms are just beginning to form more alliances with big pharmaceutical companies to secure the much needed financing for drug and device development. Big pharmaceutical firms and VCs are also acquiring the small biotechnology companies and increasingly invest in the NCE itself, preferring to build project-focused companies especially in Quebec.

The governments of Quebec and Ontario established the Quebec-Ontario Life Sciences Corridor to leverage resources and compete globally. This corridor is a physical space that connects both provinces and is comprised of the majority of the province's bioscience assets - financing, talent and infrastructure.

4.4.2 Theoretical Findings

I evaluated the Quebec and Ontario cases while testing the three hypotheses. The Quebec case supports *Hypothesis 1: A strong KOST in place prior to a global financial crisis is likely to maintain a high commitment strategy afterwards.*. The Ontario case supports *Hypothesis 2: A weak KOST in place prior to a global financial crisis is likely to maintain a mixed commitment strategy afterwards.* Neither case supported *Hypothesis 3: When no KOST is present prior to a global financial crisis a low commitment strategy is likely to persist afterwards.*

Quebec took a strategic approach towards developing its bioscience industry both prior to and after the 2008 global financial crisis. Before the crisis a few strong KOSTS were present in three bioscience clusters including Montreal, Quebec City and Sherbrooke. After the crisis BioQuebec and the Ministry of Economy, Innovation and Export helped to facilitate a meta-network of KOSTS. Organizations within the network contributed to the province's new bioscience strategy while continuing to design and implement their individual strategies.

Quebec engaged in a coordinative process in response to a sudden decrease in industry size and financing. The KOST regained consensus around industry and economic development goals by deliberating regularly. The learning and negotiation process generated a new understanding of stakeholder interests and preferences as well as how to frame challenges and opportunities. It produced new goals focusing on personalized medicine and technology commercialization. The results are changed but complementary institutions facilitating collaboration projects, interdisciplinary training, alliances among firms, and government and university R&D. Quebec's tradition of public-private sector coordination around shared industrial development goals created learning structures that enabled the province to quickly respond to the financial crisis. It adapted to new institutions while maintaining institutional complementarity.

Ontario suffers from old industrial structures framed within a "states versus markets" mindset applied to bioscience. A weak KOST existed prior to the 2008 global financial crisis led by the Toronto Biotechnology Initiative, the province's industry association at the time, as it adapted to capture opportunities offered by the new biotechnology. After the crisis multiple strategy communities began to vie for influence and resources. The incumbent industry association reorganized to encompass a broader societal membership from students to large pharmaceutical firms. At the same time a new industry association established itself speaking for a missing constituency, small and medium-sized biotechnology firms stuck without financing or much needed commercialization expertise. The two associations now compete instead of coordinate to represent industry through a single voice.

While the competition has increased stakeholder representation and raised awareness of problems specific to small and medium-sized biotechnology firms, it weakened relations with the lead government ministries at the time. These included the Ministry of Economic Development, Trade and Employment and the Ministry of Research and Innovation. Government views this fragmentation as inhibiting the ability of Ontario to reach its potential. Not only does this fragmentation slow knowledge spillovers among bioscience firms internally, but externally it sends mixed signals to potential FDI. The ministries are now incentivizing the industry associations to either coordinate or merge. These multiple policy communities have engaged in disruptive social learning as they strive to capture the benefits of biotechnology but the fragmented nature of the bargaining process continues to steer the province along a *mixed level of commitment* to the bioscience industry.

In addition to the strength of a KOST and multiple policy communities, other variables help explain different levels of and changes in commitment strategies. These include factor endowments, size, rival industries, national institutions, and previous decisions and events (path dependence). Quebec and Ontario each produce leading scientists through their respective university systems, PROs and hospitals. This abundant factor endowment has led the provinces to continue to invest in university science and technology degrees and R&D up until the global financial crisis. But skills gaps in commercialization, engineering and translational research have slowed progress in each province as they learn how to address these weaknesses.

Quebec and Ontario are large, industrialized provinces. Rival industries like automotive, plastics, aerospace, wood products, textiles and others compete with the growth industries of bioscience and information communications technologies for financial and human resources. Quebec's industrial policy involves investing more in

R&D and in science and technology industries like aerospace, bioscience and ICT. The province and the federal government are embracing the "bioeconomy" concept where bioscience cuts across several industries creating a multiplier effect on the economy. It can not only create highly skilled jobs but produce less expensive, more effective therapies and technologies. Ontario refrains from formal industrial policies preferring to let industry lead. But industry is fragmented and has created different strategies based on competing interests leading to mixed levels of commitment.

National institutions in finance and skill development are distributed throughout the provinces. These range from R&D financing to tax credits for skills training within firms to Centers of Excellence in research. This distributed system is coordinated with provinces and city-level bioscience clusters. However, Quebec has been more strategic than Ontario in leveraging federal IPR and financial resources.

The global financial crisis of 2008 negatively affected the bioscience industry in both provinces. Since finance is crucial to R&D and innovation in biotechnology we would expect firms tied to finance to fail, be acquired, merge with large pharmaceutical firms, or develop alliances to secure needed financing. Evidence from these two cases supports this claim. We can also infer that Ontario maintained its mixed commitment partially because of the crisis. But it does not explain why Quebec remains highly committed to the industry.

Previous decisions and events impacted the paths that each province took to establish a bioscience industry. They help to explain why Quebec created a strong KOST and maintained its high commitment and why Ontario maintains its mixed commitment. The next chapter compares the four Atlantic Provinces and their efforts to create commitments towards bioscience.

CHAPTER 5

ATLANTIC CANADA:

COMMITMENT STRATEGIES IN ASPIRING BIOSCIENCE REGIONS

5.1 Introduction

Small, aspiring bioscience regions face distinct economic challenges. Scarce human and financial resources, isolation from markets, weak capacity to engage in R&D and commercialize discoveries all constrain the Atlantic Canadian provinces' ability to establish and sustain a bioscience industry. Despite these weaknesses, New Brunswick (NB), Newfoundland (NL), Nova Scotia (NS) and Prince Edward Island (PEI) are restructuring their economies to compete globally by balancing traditional industries with knowledge-based ones.

In these provinces many of the traditional industries upon which their economies have depended for decades including agriculture and fisheries form the basis for new product and technological development as they progress along the value-chain. They also underpin bioscience creating a collection of resource-based R&D and product development activities in functional foods, nutraceuticals, agricultural biotechnology, marine biotechnology, pharmaceuticals as well as medical devices and contract research organizations (CROs).

While the Atlantic Canadian provinces share common histories, institutions and infrastructures, at the micro level they commit differently to the bioscience industry. I argue that even the smallest of provinces like PEI can begin to chart a path towards a sustainable bioscience industry. Its strong knowledge-oriented strategy team (KOST) has created and implemented a holistic, high commitment strategy. And it is not always the case that the largest province, Nova Scotia, with more resources will easily sustain high commitments. The province has struggled to maintain its industry's early growth spurred by individual firm strategies and selective government interventions. A weak KOST helps to explain Nova Scotia's mixed commitment strategy.

Overcoming path-dependent strategies that lead to industrial and economic decline is the overall challenge. The different ways in which actors engage in social learning and iterative bargaining help explain variation in commitment strategies. These different commitment levels and changes in them offer implications for industry development.

The four Atlantic provinces are less developed regions within Canada. We should therefore expect no significant commitment to the bioscience industry or changes in it after the 2008 global financial crisis given the regions' scarce resources, small size and income levels below the national average. The evidence contradicts expectations. The presence and strength of a KOST, competing policy communities, different natural resources, rival industries and national institutions explain varying levels of and changes in commitments to bioscience.

PEI represents a *least likely case*. Its small size and limited resources have historically been liabilities. Individual decision-makers with experience in government, the bioscience industry and university research led the creation of a strong KOST and a niche strategy prior to the 2008 global financial crisis. *High, holistic commitment levels continue* today. The disruptive nature of social learning combined with a coordinated negotiation process underpins the industry's success.

Individual firm strategies in Nova Scotia have coordinated economic activity in bioscience despite early attempts to develop an industry-led strategy. The industry association facilitates information, best practices and networking rather than designs and mobilizes sustained support for a strategy perceived to be "picking winners". By 2014 Nova Scotia began to change its approach calling for a fundamentally different way of governing its bioscience industry. It calls for a collaborative approach across levels of government and sectors that requires changing attitudes and investing in necessary skills. This new strategy places a higher value on coordination and social learning among public and private sector organizations compared with past policies. But it is too early to determine its effectiveness. A weak KOST *maintains a mixed commitment strategy*.

Newfoundland's history of "catching up" to other provinces in terms of economic and social development combined with its discovery of offshore oil and gas has detracted from significant investment in R&D and knowledge-based industries. While policy communities developed over time, the political process was fragmented and pulled in different directions by competing industrial, economic and health interests. The result is a shift *from low to mixed levels of commitment* to bioscience.

Fragmented, government-led policy communities prevented high level commitments to bioscience in New Brunswick. The province increased investment, created new finance vehicles, began to balance innovation and support for value-added industries, and called for internationalization of the province. But the province has not developed "learning-by-learning" structures that aggregate interests among bioscience stakeholders, facilitate regular deliberations that change strategy in light of new information and create competencies along the way. Most institutional changes are the result of reviewing past policies and making incremental changes to them. With government leading, there is little consensus from industry around goals and implementation of them. The province moved *from low to mixed levels of commitment* to bioscience before and after the 2008 global financial crisis similar to Newfoundland. The rest of this chapter evaluates each case in detail.

5.2 Research Questions, Design and Method

The questions posed in this chapter address more the reaction to the 2008 financial crisis than the technological discoveries of the 1980s. Rather than assuming that provinces developed explicit responses, I ask *did* they change or create specific economic strategies, policies and institutions to shore up knowledge-based industries? Since the provinces are small and few have mature bioscience industries, were these affected at all by the sudden scarcity of financial resources globally? If the provinces were affected, how and under what conditions did public and private sector actors design institutions to solve the problem of expanding the bioscience industry's opportunity structure while simultaneously de-risking investments in it? Why do these regions develop and change levels of commitment to bioscience despite operating within the same national political economy and sharing similar histories?

Using a most similar systems approach, this chapter compares four Atlantic Canadian provinces – Nova Scotia, New Brunswick, Newfoundland and Labrador, and Prince Edward Island – and their attempts to develop and implement bioscience industry strategies. This approach enables the researcher to draw conclusions specific to small, rural bioscience regions that are generalizable to similar regions in other countries. It also provides a more complete picture of Canada's changing bioscience industry.

The research continues the structured, focused approach to compare case studies over time and asks the same questions of each. Data was collected from semi-structured interviews, scholarly papers, policy reports, government statistics and other public documents. CEOs, researchers, industry association leaders and managers as well as policymakers within both provincial and national government support organizations were interviewed. The study also draws on the author's many years of international trade, foreign direct investment and firm-level strategy work in these provinces.

Section three compares industry innovation and growth among the provinces as background from 1997 – 2007 using descriptive statistics. Bioscience industry statistics are notoriously difficult to measure and compare. Each jurisdiction selects data that portrays their industry positively in order to compete for FDI and resources. For example, while some provinces attempt to distinguish between core biotechnology firms and those that *use* biotechnology, others do not and even include firm and employee counts in healthcare services. The difference can be hundreds of employees versus thousands. This research separates out measures of core biotech firms, number of employees and other indicators from the broader healthcare industry. This section also helps facilitate controlled comparisons of provincial strategies and institutions by highlighting shared federal institutions.

Section four briefly evaluates the innovation systems and evolution of strategies and institutions in each province up to 2007. This part necessarily lays the groundwork for understanding whether path dependence or the diffusion of ideas and institutions eventually permeated individual provincial responses to the 2008 financial crisis. Section five then examines in more detail the role of policy communities and KOSTs as they learn and bargain for each province's choice of commitment strategies in reaction to the 2008 financial crisis. Section six concludes.

5.3 Descriptive Statistics: Comparing Atlantic Canadian Provinces

As indicated in Table 1, since the 1980s, the bioscience industry in the Atlantic Canadian provinces has grown in terms of the number of companies, revenue, R&D spending, number of employees and new product development. By investing in the necessary infrastructure and providing critical institutional support, the number of firms has increased, for example, in Nova Scotia from 28 to 50 during 2002-2009, in New Brunswick from six to 25 during 1997- 2007 and in Prince Edward Island from 15 to 29 during 2005 - 2009.

But sustaining growth has proven more difficult. While there are several arguments as to why, from the lack of diversified sources of risk finance to a scarcity of human resources with requisite skills and experience commercializing technologies, I argue that the causes are deeper. A lack of understanding of the industry by government, fragmented industrial structures, few institutions that facilitate social learning among a broader range of industry stakeholders and often conflictual bargaining processes pitting competing interests between traditional and knowledge-based industries all precede other specific challenges.

5.3.1 Structure and Nature of the Industry and Markets

The bioscience industry in the Atlantic Canadian provinces is comprised of a relatively small number of diverse firms including privately owned start-ups, a handful of anchor companies, industry associations, provincial and federal research organizations, hospitals, technology incubators and economic development agencies. Government finances R&D in most provinces. However, in Nova Scotia the region's largest cluster, the private sector finances most R&D. The majority of its products are exported as functional foods, nutraceuticals and pharmaceuticals. Those firms that have moved beyond the R&D stage to commercializing technologies export most products given the small regional market.

One or two large firms such as Novartis, Biovectra, Genzyme, Acadian Seaplants Limited, Abbott, Pfizer Canada, and Cooke Aquaculture anchor each bioscience cluster. Many small firms engage in a range of relationships from R&D to subcontracting for

CRO services to in-licensing and out-licensing of new technologies. The diversity of relationships represents a variety of growth strategies.

Below are bioscience industry statistics up to 2007 for each of the four Atlantic Canadian provinces. Each province developed significant yet different bioscience assets and each grew during this period. These resources coupled with federal and provincial support for infrastructure and R&D funding bolstered capabilities. Private sector investment drives R&D intensity in Nova Scotia, which is much lower in the remaining provinces.

Despite these relatively positive statistics an underlying skepticism and concern for the lack of bioscience industry sustainability exists in each province except PEI.[102] NS, NB and NL claimed that they had not yet created a true bioscience cluster, which reveals that all four provinces seek this goal. It also signifies that cluster theory is permeating many federal and provincial bioscience strategies.

The next section briefly analyzes the evolution of bioscience commitment strategies in Atlantic Canada up to the 2008 global financial crisis. These provinces started much later than Quebec and Ontario in capturing the benefits of new biotechnologies so the focus is more on changes in the business environment and policy communities. The approach provides useful background for a deeper examination of responses to the 2008 global financial crisis.

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[102] Conculsions based on interviews with industry stakeholders and analysis of official government and corporate strategy documents.

Table 11 Atlantic Canadian Provinces Bioscience Statistics (2005/7)

Province	New Brunswick	Newfoundland & Labrador	Nova Scotia	Prince Edward Island
Population	754,914	526,977	942,688	146,283
Core Research/Industry Areas	Plant science, forestry, agriculture, marine, biomedical	Bioinformatics, marine/aquaculture, genomics	Bioproducts, nutraceuticals, digital health, CROs, medical technology	Bioactives with applications to human, marine, animal health
# Patent	122	N/A	307 (222 Industry; 85 Research Institutions)	N/A
# Bioscience firms	6 to 25 from 1997- 2007	20	28 to 50 from 2002-2009	15 to 30 from 2005 – 2009
Corporate Annual Sales (US$ million)	110 million in bioscience 226 million from forestry, fisheries, agriculture, environmental)	16 million (medical devices; omega 3 oils)	181 million	61 million
Industry Employment	120 Full time 415 Seasonal (2,000 direct + indirect in 2009)	533	1,100	750 (Industry 500; Research Institutions 250)
# Products (1997-2007)	210 (plus 102 in pipeline)	N/A	480 (plus 306 in pipeline)	N/A
# Universities with Bioscience Degrees	3	1	8	2
Research Institutes (Fed + Private)	10	1	20	18
Research Employees	788	840	2,365	250
R&D - Value of research projects	N/A	192 million (137 industry; 55 Research Institutes)	163 million (53 Industry; 110 Research Institutes)	134 million (38 Industry; 96 Research Institutes)

Source: Collected by the author from Statistics Canada, asset maps and overviews developed by the bioscience industry associations in New Brunswick, Newfoundland & Labrador, Nova Scotia and Prince Edward Island. Numbers are rounded.

5.4 Bioscience Industry and Strategy Evolution: 1980 – 2007

5.4.1 Industry Evolution

Technological changes during the 1980s – 2007 affected the four Atlantic Canadian provinces, historically the poorest, smallest and most remote of Canadian regions, differently compared to the wealthier, industrialized provinces of Quebec and Ontario. Atlantic Canada relied more on traditional agriculture, marine and food related industries for economic growth. Each province benefits from the same federal economic institutions such as the Atlantic Canada Opportunities Agency (ACOA) that delivers programs and funding designed to help them "catch up" to the rest of Canada. Despite these similarities, each province pursued a different path towards transitioning to a knowledge economy. These paths were influenced by each province's previous policies as much as their efforts to access lessons learned from other jurisdictions. Furthermore, while benefiting from these formal federal and provincial programs, other stakeholder groups including industry associations, individual firms and the universities developed their own strategies.

The key challenge during the 1980s and 1990s for Atlantic Canada was, given constraints on natural and human resources, how to create the *capacity to learn* both within and among government agencies, firms and the university. Alongside investing in physical assets like new research labs and technology incubators as well as providing R&D financing, creating the assets and the mechanisms that facilitate *how and what to learn* about the economic benefits of science-based industries and how to translate scientific discoveries into marketable products leading to highly skilled jobs and wealth creation was also necessary. But entrenched, traditional interests in agriculture and the fisheries combined with weak understanding of the bioscience industry challenged fundamental economic restructuring.

To sustain economic development, the Atlantic Canadian region during this period relied heavily on a combination of federal government transfer payments through ACOA, improved productivity in traditional industries and R&D and infrastructure investment in knowledge-based industries. Despite these latter investments, they are relatively easy to establish and represent a lower rather than higher commitment to knowledge-based industries as a source of technological innovation and economic development.

It was not until around the time of the 2008 financial crisis that some provinces began to make higher-level commitments toward the bioscience industry and to knowledge-based industries generally. The financial crisis created a sense of urgency to do something in the face of increasingly scarce resources and global competition across the economy. I argue that while Prince Edward Island and Nova Scotia established bioscience strategies prior to 2008, these formed part of a larger knowledge-based industrial growth plan targeting multiple industries. Furthermore, only Prince Edward Island established, implemented and regularly monitored and evaluated a formal bioscience strategy beyond the crisis. The overviews below describe and analyze each province's bioscience assets and industrial structure.

5.4.1.1 New Brunswick

New Brunswick's bioscience industry grew between 1997 and 2007. Bioscience in the province stems from its traditional industries including marine, agriculture and forestry. Areas of innovation within these niches include plant science, potato development, native berries, and aquaculture including the introduction of "green" fish therapies, fish brood stock, new fish species, and crop-specific biofuel technologies. The majority of biotechnology firms in New Brunswick are small. Some are innovative while most conduct R&D through government grants. Acknowledging the critical role that anchor firms play in New Brunswick's innovation system, one interviewee expressed that "bioscience firms exist in the service of traditional anchor firms."[103]

McCain Foods and the Irving Company anchor the bioscience industry. McCain Foods is a multi-billion dollar company with core competencies in agriculture and notably is a global supplier of French fries. The firm leads New Brunswick's potato innovation cluster. Over 75 companies and research organizations engage in research and commercialization projects. The Irving Company owns 75 per cent of New Brunswick's forests and is viewed as a major steward

[103] Author interview, Fredericton, New Brunswick, July, 2010.

of the province’s natural resources. Despite these resources the industry remains fragmented with little social learning occurring. No bioscience industry association existed during the period to aggregate interests, create consensus around goals, tasks and responsibilities and collaborate with government on strategy and resources.

5.4.1.2 Newfoundland and Labrador

An island jurisdiction located in the eastern most point of North America, the Newfoundland and Labrador bioscience industry comprised 20 firms. Activities included niche areas of genomics, marine biotechnology, aquaculture, and health information technology. These three application areas build on the province’s long reliance on the sea for economic growth opportunities. In addition, its founder population 98 percent of which is traced back to immigrants originating from England and Ireland during the 1700s provides a competitive advantage in the area of human genomics. This population carries genes associated with common diseases like diabetes. Since the island jurisdiction is “genetically isolated,” it is easier to identify these genes that can be useful in developing therapies (Rahman et al., 2003, p. 167). University researchers at Memorial University continue to lead this research and collaborate with similar jurisdictions like Iceland.

Commercializing discoveries and attracting FDI were enormous hurdles during this time despite these strengths. Federal and provincial governments primarily financed university research even though disbursements through the Atlantic Innovation Fund to individual firms continued. No bioscience industry association or anchor firm existed during this time. Competing industries including offshore oil and gas shifted attention away from knowledge-based industry development.

5.4.1.3 Nova Scotia

Nova Scotia specializes in disease diagnosis, treatment and prevention, marine biotech, bioproducts, functional food and nutraceuticals, and medical technology. R&D is conducted both within firms as well as in research institutes from the National Research Council Institute for Marine Biosciences to Dalhousie University. Leading firms include Precision BioLogic, founded in 1983 by a scientist turned entrepreneur, which produces diagnostic coagulated reagents and controls to test blood samples; Acadian Seaplants; and, Ocean Nutrition Canada as well as many smaller firms in either product-ready or R&D stages. Overall, the province's bioscience industry serves the global market given local market scale limitations. The industry produces and exports over US$80 million in functional foods and nutraceuticals, US$55 million in pharmaceuticals, $25 million in agricultural bio products, and US$20 million in medical diagnostics. Medical device manufacturers, clinical research organizations and bioinformatics/software product exports are minimal (BioNova, 2007).

Nova Scotia developed industry partnerships in the early 1990s to capture the opportunity to create a bioscience industry. From the beginning it was industry, not government agencies that mobilized itself up until 2005 when asset maps were completed but no strategy was developed.

5.4.1.4 Prince Edward Island

Prince Edward Island's bioscience cluster includes bioactives-based research, product development and commercialization for human, animal and fish health and nutrition. Its 2005 strategy outlined specific areas of focus and goals that were developed through participatory governance led by the government and transferred to the PEI BioAlliance industry association. Explicit goals included increased private sector employees and revenue by 2010. By 2009 70% of bioscience revenue was still derived from government grants through specialized R&D financing programs (S. Casper, Krause J., MacNevin A., 2010).

In response, government has acted as a platform for which mostly small firms conduct both basic and applied research. Larger firms like Biovectra, Genzyme, Chemaphor and Stirling Products demonstrated differing levels of local and global network connectedness based on how reliant their products were on local strengths including natural health products and some pharmaceuticals for animals and humans. This condition is due primarily to the historical R&D strength of PEI's Veterinary College, local agricultural and marine resources as well as subsequent interest from foreign investors for which these companies depend.

The above overviews indicate that each province developed significant bioscience assets and each grew its bioscience sector during this period. However, each made different strategic choices in terms of what areas of bioscience to invest, develop skills and how to growth the industry either through local firm and FDI support or both.

5.4.2 Strategy Evolution

It was not until the middle to late 1990s that provinces like Prince Edward Island and Nova Scotia along with industry associations and their universities began to coordinate and develop strategies to transition towards a knowledge-based economy. And it was not until the mid-2000s that only one province, Prince Edward Island, began to design and implement a transformative bioscience cluster development strategy. The table below chronicles key strategies, governance organizations, individuals and triggers during this period.

Prince Edward Island’s Premier, Robert Ghiz supported the new focus on strategies favoring knowledge-based industries:

> As a single community, working together on big goals and new ideas, Prince Edward Island is poised to begin a new and innovative chapter…The status quo is unacceptable because yesterday’s path neglects our province’s advantages, strengths and possibilities. (Mayne, 2005, p. 3)

As a result, the number of firms, new skills and institutions grew significantly as well as a more responsive labor market associated with new university degree programs in microbiology. Previous bioscience growth in PEI was very incremental though initial success in the 1980s was led by Dr. Regis Duffy who left the University of PEI to found BioVectra, now PEI’s leading bioscience firm.

Nova Scotia’s growth up until 2007 was largely led by individual firms, networking assistance from the industry association, BioNova, and finance from its VC organization, Innovacorp, while provincial and national government partners largely maintained established R&D grant, tax and market access programs. And even though a provincial asset map was created in 2005, no strategy followed. Industry actors led growth and even viewed government with suspicion, not wanting them to “pick winners.”[104] While Nova Scotia overall sells more new products, its bioscience growth was driven by existing firm expansion through sales to export markets rather than through the establishment of new firms (BioNova, 2007). Nova Scotia established institutions and governance organizations over time beginning in the early 1990s up to 2007, but individual firms sustain growth through their own strategies, alliances and access to labor, finance and markets.

During this period, the bioscience industry in New Brunswick was fragmented and involved no real province or industry-led bioscience strategy. Despite no formal strategy, application-specific bioscience clusters have established themselves in different regions of the province, from marine bioscience in the Acadian Peninsula to plant bioscience in the Fredericton-River Valley, over time. Large, “home-grown” anchor firms in forestry such as the Irving Company and in agriculture including McCains have led this growth. In addition, federal programs including IRAP R&D grants and a single provincial initiative, the New Brunswick Innovation Fund, have contributed to more effective financial institutions. And the industry association, BioAtlantech, now known as Bio New Brunswick (BioNB) is showing signs of mobilizing resources to support research and commercialization particularly of products derived from the province’s natural resources. However, there has been little social learning up until now other than through an informal network of bioscience specialists in both the public and private sectors who meet and communicate infrequently.[105]

Newfoundland’s bioscience industry was also fragmented and comprised primarily of university research with just a few small bioscience firms. Social learning can be characterized as incremental and the political process of choosing among alternative economic development strategies was fragmented. While the province has developed general economic development strategies, touching on bioscience among other industries, during this period a more formal bioscience policy community did not exist nor did the province produce a specific strategy in coordination with industry. The province’s capitol, St. John’s, includes the only university, Memorial University along with most firms and the important Newfoundland Center for Health Information. While the province established BioEast, its bioscience industry association in the

[104] Author interview, Halifax, Nova Scotia, July, 2010.
[105] Author interview, Fredericton, New Brunswick, July 2010.

early 2000s, this institution was largely unsuccessful and later folded into the Newfoundland Association of Technology Industries (NATI), a more broad-based high technology industry association. Newfoundland's commitment to developing bioscience was low during this period.

Finally, the majority of firms derived revenue from federal and provincial R&D grants from the NRC, ACOA and the province's economic development agency, the Department of Innovation, Business and Rural Development (IBRD). During this time, Newfoundland did not create or change many bioscience institutions related to finance skill development or corporate governance nor did it create a province-wide bioscience strategy.

Table 12 Governance Organization, Policy and Key Individuals by Province (Pre-2008)

Province	Governance Organizations	Policy	Key Individuals
Prince Edward Island	2005 – PEI BioAlliance established as catalyst mobilizing other national, provincial and private sector entities 2005 - Island Prosperity Program 1990s – First coordination effort: “Belvedere life sciences group” – Public/private partnership	1999 – Knowledge Economy strategy 2005 - Strategy for PEI Bioscience 'Cluster Development'; Funding for scale-ups; Building of biocommons facility – research, production; Bioscience Human Resource Strategy;	Dr. David Mayne, former Deputy Minister, Innovation and Advanced Learning, former Lead Scientist at PEI’s NRC - INH Wade Mclauchlan, current PEI Premier, former University of PEI President. Supporter Island Prosperity strategy Dr. Regis Duffy – former UPEI Professor – Founder, BioVectra – first successful bioscience firm in province Rory Francis – former Deputy Minister in several PEI gov’t departments; Executive Director PEI BioAlliance non-profit network of bioscience organizations
New Brunswick	BioAtlantech (federally and provincially financed) Business New Brunswick, Industry Canada, Department of Fisheries, Agriculture	Largely top-down/federal strategy No substantive provincial policy up until 2012	N/A
Newfoundland & Labrador	IBRD – Gov’t Econ Dev. Agency NATI – Technology Industry Assoc. (absorbs BioEast industry assoc. founded in early 2000s) 2008 - First coordination effort: “Ramada group” breaking silos in health IT. 1996 - NL Centre for Health Information	No written strategy, but do have goals Health information network - 1996	Craig Dobbin (Craig L. Dobbin Genetics Research Centre, MUM)
Nova Scotia	Atlantic Canada Opportunities Agency InNOVAcorp, the National Research Council, Institute for Marine Biosciences, Nova Scotia Business Inc. and the Nova Scotia Office of Economic Development 2005 – Back to individual organizations facilitating growth 2000 – Life Sciences Development Assoc. 1997 – Life Sciences Industry Partnership 1993 – First coordination effort: BioNova Biotech Working Group	2005 - Mission accomplished. LSDA to close. New asset map completed. No new province-level strategy/policy. Firm-led growth with BioNova and InNOVAcorp facilitating finance, technical assistance, access to markets and networks 2000 – accelerate growth with new development plan & federal/provincial funding 1997 - link scientists, business partners, universities, and government agencies in the biotech industry 1993 - Initial establishment of industry vision & stakeholders	N/A

Source: Data collected by the author from provincial bio-asset maps, industry association web pages and interviews

5.4.3 Conclusion

The above analysis uncovers the evolution of different bioscience industries, governance structures and strategies among the Atlantic Canadian provinces between the 1980s and 2007. Despite these differences they all contain anchor organizations such as federal or provincial government agencies, university medical schools and science departments, industry associations, FDI or individual homegrown firms and relied significantly on government R&D grants.

Prince Edward Island created and maintained a bioscience strategy driven by a strengthening KOST. Industry led Nova Scotia's early success as it mobilized stakeholders and created a bioscience strategy. But by 2005 individual firm strategies guided industry with the mindset that government should not "pick winners". In both provinces enlightened individuals with science, government and industry experience led strategy. New Brunswick and Newfoundland struggled and maintained low commitment levels despite investments in infrastructure, R&D and pockets of success from plant science to marine biotechnology. Competing policy communities prevented holistic and even mixed levels of commitment to bioscience.

5.5 The 2008 Global Financial Crisis: A Change in Commitment Strategies?

After the 2008 global financial crisis, PEI maintained a high commitment to its bioscience industry while Nova Scotia maintained its mixed commitment. New Brunswick and Newfoundland both made changes to finance and skill development but neither took a holistic approach with new overarching goals guiding it. Both provinces shifted from a low commitment to mixed commitment strategy.

5.5.1 Problem-Focused Approach: Balancing Traditional and Knowledge-Based Industries

The problem in Atlantic Canadian provinces post-2008 financial crisis was less about the shock's immediate effect on access to finance and more on how to balance growth, diversify finance and commercialize technologies. Traditional industries such as forestry, fisheries and agriculture whose firms were trying to move up the value chain competed with investment in knowledge-based industries. The challenge was how to diversify sources of risk finance away from government-funded R&D toward "angel" investors, government-backed, privately managed VCs, partner financing, out-licensing and sales of new technologies and products. Similar to Quebec and Ontario smaller provinces struggled to translate basic research into commercial technologies.

Provinces believed that diversification of finance would relieve pressure on government budgets and help facilitate industry growth.[106] The Atlantic provinces began to focus on products with shorter times-to-market and entered at different points along the value chain. Larger clusters like Quebec and Ontario worried about filling the financing gaps along the entire process of discovery, development and distribution of bioscience products.

Smaller jurisdictions understand they cannot be "all things to all people" and must focus on their competitive advantages. Some strategies are relatively successful such as PEI's focus on bioactives with application to human and animal health. Even established biotech regions must find their competitive advantage. After 2008 Quebec stakeholders agreed to concentrate on personalized medicine.

In addition to how to create a strategic focus all provinces are concerned that "we're growing them to leave...how much do we support them?"[107] For example, a NL aquaculture firm was purchased by VCs in British Columbia and transferred its R&D and product commercialization to that province. FDI is also moving out of Ontario after benefiting from tax credits and other incentives over the years. The challenge is how to retain homegrown firms, attract and keep FDI, and facilitate spillover effects conducive to growing the industry.

The data in Table 3 indicates change in bioscience commitment strategies across the three institutional areas and all four provinces since the 2008 financial crisis. The data helps to understand whether or not finance, skill development and corporate governance rules and norms became complementary representing a holistic/high commitment strategy.

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[106] Atlantic Canadian provinces were vulnerable since government budgets including ACOA were exposed to potential cuts despite Canada's ability to initially withstand the global financial crisis.

[107] Author interview, St. John's, Newfoundland, November, 2012.

Table 13 Bioscience Finance, Skill Development and Corporate Governance (Pre/Post-2008 Financial Crisis)

	Finance	**Skill Development**	**Corporate Governance**
1st Order – Settings	**Biotech R&D spending (US$)**	**Tax Credits – Scientists, Technical specialists**	**Make or Buy Decision – Amount of R&D in-house**
New Brunswick	**↑Fed/Prov funding–2006 - $1,718,967 -** 10.1% growth in R&D funding to universities from 1993-2006; Largest single NBIF invest in bioscience - $1m in 2013; **↓Fed funding -** ACOA/AIF funds 74% from 2007-13.	**Provincial credits mostly for university researchers**/research institutes, not corporate researchers/managers	**Mostly in-house** (largely unchanged); out-license technologies
Newfoundland& Labrador	**↑Fed/Prov funding -2006 - $5,524,003 -** 10.1% growth in R&D funding to universities from 1993-2006; **↑Fed funding**– ACOA/AIFfunds 260% from 2007 – 2013. **Note:** fastest growth in fed R&D	**2007** – No provincial S&T skills tax credit. But access to federal sources; **2014** - NL R&D Corp provides 75% of the salary for a Ph.D. graduate in science or engineering. **Note:** little indication that bioscience is targeted	**Mostly in-house** (largely unchanged); out-license technologies
Nova Scotia	**↑Fed/Prov funding - 2006 - $28,659,659** -10.1% growth in R&D funding to universities from 1993-2006; **↓Fed funding -** ACOA/AIF funds 74% from 2007-13. **Note:** highest amount of Gov't R&D, but also highest private sector	**Pre – 2008** - 15% R&D tax credit No change in settings	**Mostly in-house** (largely unchanged); out-license technologies; increased global sales
Prince Edward Island	**↑Fed/Prov funding - 2006 - $804,616 –** 23.8%growth in R&D funding to universities 1993 – 2006; **↓Fed funding -** ACOA/AIF funds 13.5%; ↑ **overall R&D Invest 48% 2004 - 2011**- leveraging private invest **Note:** fastest increase among provinces	2012 - Specialized Labor Tax Credit on Personal Income	Mostly in-house; increased density of local bioscience network; increased number of ties between PEI, Canadian and global organizations; Nature of relationships have changed to include financing from foreign customers, R&D partnerships, sales; increase out-license technologies
2nd Order – Techniques	**Diversification of finance sources**	**Program Changes**	**Diversity of R&D models**
New Brunswick	2013 – expansion of existing programs; BUT Few if any NBIF VC investment in bioscience firms; Some in agriculture/food-related. Mostly digital media/ICT applications.	2013 – 3 New Brunswick Innovation Research Chairs, 1 Biosciences, 1 Medical Devices to work directly with industry on applications; expansion of existing programs	Little change. Mostly individual firms leveraging provincial and federal sources of R&D funding. AIF (ACOA) Funding – requires Advisory Board for each corporate recipient of R&D grant;
NewFoundland & Labrador	2009 – New RDC founded. Funding for proof of concept, prototyping; federal sources No Invest in bioscience firms yet. No formal bioscience strategy 2014 – new Venture Capital Tax Credit; Two Venture Capital Funds – Gov't. But, horizontal approach. No bioscience invest yet.	2007 – SR&ED; 2014 – RDC S&T skills tax credit program. $1m annually.	Little change. Mostly individual firms leveraging provincial and federal sources of R&D funding. AIF (ACOA) Funding – requires Advisory Board for each corporate recipient of R&D grant;
Nova Scotia	Gov't agency reorganization NSBI/Dept. Econ. Dev. "OneNS"; federal sources; Innovacorp 30% investment in bioscience firms; No formal provincial	2007 – no MBA biotech-focused program; Dalhousie law school training patent lawyers; Dalhousie medical school training researchers;	 AIF (ACOA) Funding – requires Advisory Board for

	bioscience strategy	medical technician training at NS Community College & Univ. Cape Breton 2014 - Workplace Innovation and Productivity Skills Incentive (WIPSI); Productivity and Innovation Voucher; SR&ED	each corporate recipient of R&D grant;
Prince Edward Island	New - Discovery & Dev. Fund; provincial-NRC partnership; non-local partners with PEI firms provide financing New - Bioscience Tax Incentives (to biotech firms)	2010 – MBA program in Biotech Management at UPEI; Holland College Centre for Labour Force Innovation – 2 year Bioscience Technology Program; Review of Provincial Immigration Policy 2012 – education/training program for QA/QC and Regulatory Affairs Specialists	PEI firms increased # partnerships with global firms in areas of finance, market access, R&D collaboration projects. AIF (ACOA) Funding – requires Advisory Board for each corporate recipient of R&D grant;
3rd Order – Overarching Goals (Paradigm change)	**Core focus shifting (e.g. basic-commercial research, niche application areas, niche science areas, global partnerships)**	**Core focus shifting**	**Core R&D strategy shifting**
New Brunswick	No significant change	No Change	No Change
NewFoundland & Labrador	No significant change.	No Change	No Change
Nova Scotia	**Change in Overarching Goals:** Collaboration; Fundamental change in attitudes, people and economic growth; Private sector led growth	Greater government intervention through skills incentives; OneNS focusing on “people”, investing in them	Balance Individual firm strategies with project Collaboration among partners; private sector-led growth, but partnerships with gov’t
Prince Edward Island	Paradigm shift began in 1999. Continuation of strategy, with regular 3-year evaluations, developed in 2005. **No change in overarching goal since 2007.**	Province-wide HR development strategy (in collab. with federal agencies)	Focus on Collaboration projects Firm Internationalization Continue to support the role of the Board of Directors of PEI BioAlliance, Inc. as the mechanism (“Innovation Intermediary” for aligning vision, setting priorities, and allocating resources to achieve goals

Sources: Provincial industry strategy documents; Government R&D spending - CIHR, NSERC and CFI in NATI report; AIF evaluation by author; Annual reports

5.5.1.1 New Brunswick

New Brunswick made changes to finance and skill development institutions but did not pursue a high, holistic commitment strategy with overarching goals guiding it. Policy communities and separate niche bioscience clusters existed in different parts of the province. And even though New Brunswick created a lead agency, BioAtlantech in 1997 which transformed into Bio New Brunswick (BioNB) in 2014, to mobilize bioscience interests and execute strategy, the process is still evolving. No KOST developed resulting in a mixed bioscience commitment strategy.

Policy Communities and a Mixed Commitment Strategy

New Brunswick's response to the 2008 global financial crisis was led by successive government policies, not industry. Government restructured and created new economic development agencies to balance central management with local decision-making. Newly elected officials and their policy community, not a KOST, drove change. And changes did not represent a paradigm shift in thinking about the bioscience industry. Government and industry did adjust spending levels, program types and rules governing them so that finance and skill development were more closely linked. The result was a mixed commitment to bioscience. What was missing were clear indications that firms were improving their competencies by hiring skilled labor, forming alliances among each other and externally, and investing more in R&D. The sequence of decisions and events elaborated below strengthens our understanding of the case.

In 2012 the Progressive Conservative party created a new Action Plan, "Rebuilding New Brunswick: Growing Together," stretching from 2012-2016 and designed to support six targeted growth industries, including bioscience. Sectors were chosen based on their applications across economic sectors and ability to build on existing resources and capacity. The same government restructured and renamed the province's economic development agency, the Department of Economic Development and created a new Invest New Brunswick (INB) within it.

The change reflected the province's recognition that it needed to create efficiencies, coordinate economic development efforts and balance central management with decision-making at the community level (NBDED, 2012). It also needed to ensure that the various government agencies within which target industries fell engaged in a seamless approach towards facilitating support. Those agencies that participated in the strategy would also take on an implementation role associated with action items established jointly with industry and in consultation with ACOA, the federally funded regional economic development agency. Finally, the province sought to increase its global reach by attracting more FDI.

But by 2014 the Liberal party came into power and implemented its economic development ideas. A new economic development agency was created in 2015, Opportunities New Brunswick (ONB), and incorporated the activities of Invest New Brunswick and the Department of Economic Development. The ONB differs from the previous agency in that it is a crown corporation operated by a private sector Board and CEO that applies a "client-focused" approach.[108] This organizational and institutional change is designed to help the provincial government learn from the private sector about society's needs and how to more efficiently deliver services. But it is too early to determine whether or not this new strategy will be more effective. I argue that these organizational changes are the result of political discontinuities more than industry-led commitments.

In parallel with these cross-cutting institutional and organizational changes, the province's Department of Agriculture, Aquaculture and Fisheries and the federal agency ACOA committed $622,000 to BioNB, the province's lead bioscience agency in 2013. The funds are to be used to support pre-commercialization development, training, and business case development for bioscience incubators. This action demonstrates New Brunswick's interest in encouraging commercialization of R&D in its resource industries but that government is still a key partner in the process if not driver.

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[108] See: http://www2.gnb.ca/content/gnb/en/departments/economic_development/news/news_release.2014.12.1387.html

Did financial institutions change after the 2008 global financial crisis?

New Brunswick has not benefited from significant provincial or federal investment in bioscience R&D compared to the other provinces and competing industries. Even though existing institutions are expanding like the New Brunswick Innovation Fund and its VC investment arm, most financing is committed to university bioscience and medical technology R&D through Innovation Research Chairs. Competing industries including agriculture, digital media and ICT received more funding that bioscience firms.[109]

The mindset in New Brunswick continues to view university R&D as the driver of technological innovation. Individual firms can benefit from traditional R&D tax credits, but no new corporate incentives or programs were established after 2008. However it increasingly supports university – industry collaboration projects. In 2013 the province established three Innovation Research Chairs at the University of New Brunswick in bioscience and medical devices. These chairs are tasked with working directly with industry on applications. While the investment in Innovation Chairs signals a willingness to commit to specific research programs and scientists in support of the province's 2012 strategy, there is still uncertainty about the new role of the ONB economic development agency.

Did skill development institutions change after the 2008 global financial crisis?

New Brunswick continued its 2003 talent recruitment program after the global financial crisis through its Innovation Fund that finances professors, research assistants and research technicians. However, the province's traditional industries in food, wood processing and growth industries like ICT benefit more from skill development programs.

Did corporate governance institutions change after the 2008 global financial crisis?

The way in which biotechnology firms in New Brunswick create competencies relies mainly on hiring skilled individuals and collaborating more with the university. FDI

[109] Results based on review of NBIF awards since founding. See http://nbif.ca/en/portfolio/

collaborations and strategic alliances are less common, which limits knowledge spillovers necessary to grow the industry. Firms continued to receive little if any NBIF provincial or ACOA federal funding. In fact rules governing NBIF limit disbursements to *new* rather than existing firms in the province with high product commercialization potential. Despite these limitations New Brunswick firms leverage provincial and federal sources of R&D funding more than private sector sources.

In 2014 the province counted 23 core biotechnology firms that develop new technologies and 80 that actually use them in their operations. Most individual firms are small with up to 10 employees. The founder is often a university scientist spinning off his or her company based on a discovery. The organizational structure of the firm typically includes the founder as CEO and is increasingly required to establish an Advisory or Governing Board before the firm can receive VC R&D funding through NBIF or ACOA.

The agglomeration of small biotechnology firms is complemented by two large anchor firms, the Woodlands division of J.D. Irving Company and McCain Foods. Both continue R&D investment in advanced seedling production technologies and food products including potato varietals. The Irving Company is known as a steward of New Brunswick's forests, investing in environmental projects associated with protection and cultivation of plants and trees.[110]But these firms are relatively insular and do not engage in collaboration projects with individual biotechnology start-up firms.[111]

5.5.1.2 Newfoundland and Labrador

Similar to New Brunswick, Newfoundland increased spending and developed new programs in finance and skill development as part of a normal policy process but did not pursue a high commitment strategy. Competing policy communities did not take a strategic approach toward developing the bioscience industry. Instead they began to take incremental steps to create bioscience niche areas including genomics, bioinformatics and marine biotechnology that competed with environmental and traditional industry

[110] Ibid.
[111]Author interview, Fredericton, New Brunswick, July, 2010.

interests. No KOST developed despite some competency improvements within government, Memorial University and the broad-based technology industry association.

Policy Communities and a Mixed Commitment Strategy

Newfoundland is an increasingly resource-rich province benefiting from offshore oil and gas. Its economy grew between 2003-2013 by many measures including a rise in GDP, decrease in provincial debt, and an increase in employment and private investment. These improvements had little effect on bioscience industrial policy.

The province encourages investment in the oil and gas and related industries but labor reports claim that few Newfoundlanders have benefited through employment options in this industry. And oil price volatility along with a tradition of high poverty levels, outmigration of working age population, and provincial underinvestment in social and physical infrastructure threatens Newfoundland's positive economic growth trends (Gibson, 2014).

Post-2008 Newfoundland did not establish a formal bioscience strategy within this context.[112] The province pursues potentially conflicting goals similar to other jurisdictions. Commercializing bioscience products in order to create highly skilled jobs, new firms, and retain existing firms competes with efforts to decrease healthcare costs or to conserve forests. Furthermore, there is no consensus on a strategy and work plan that will help reach these goals.

Newfoundland has pursued incremental changes. The province identified niche areas with competitive advantages – genomics, aquaculture, and health IT – but only now are they starting to integrate the various actors into a coherent entity where all assets can be leveraged. Disagreement exists within Newfoundland and between provincial and federal agencies like ACOA regarding whether strategy should cultivate big successes at the "macro" level, or, start small with discoveries from individual researchers that could turn

[112] Author interview, St. John's, Newfoundland, November, 2012.

over the longer-term into major successes.[113] Other challenges involve encouraging all stakeholders including provincial governments to take a long-term approach towards the industry with the understanding that "these things don't happen within a political time-frame."[114]

Unlike Newfoundland's prior experience of incremental social learning and relatively fragmented bargaining, coordination among stakeholders and a higher rate of institutional creation and change related to science and technology is increasing. For example, the Research and Development Corporation (RDC) was established in 2009 as a non-profit organization. It is designed to improve R&D in Newfoundland and Labrador by providing funding and leveraging university and private sources of financing. The organization operates at arm's length from provincial government.

To create RDC the government selected a CEO who then assembled a small number of individuals to help develop its organizational framework and role in supporting R&D in Newfoundland. RDC consulted different stakeholder groups across the province and researched international jurisdictions that successfully designed and implemented R&D strategies. The result is a baseline study of existing infrastructure and core R&D assets as well as lessons learned from the international study. This social learning process resulted in the creation of RDC. The institution is similar to investment agencies in other provinces that have learned that operating separately from political decision-makers can ensure that investment decisions are based on economic fundamentals rather than on competing non-economic goals. Despite this positive step, a review of RDC investments since 2009 reveals bioscience firms have yet to secure RDC investment finance. Evidence indicates that firms in the fields of geology, oil and traditional value-added industries have benefited.

Like New Brunswick, in 2014 Newfoundland created a new economic development agency, the Department of Business, Tourism, Culture and Rural Development. This agency took over implementation of activities from the former Department of Innovation, Business and Rural Development. While this change was made after the 2008 global

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[113] Author interview, St. John's, Newfoundland, November, 2012.
[114] Ibid.

financial crisis it is difficult to make the causal link between the global shock and the institutional change.

The province changes its economic development agencies' structure every few years often in relation to a new government taking power. This change could simply be a continuation of a long tradition. But it also implies that previous efforts by the province and industry association, however small and incremental, to support bioscience may not survive successive governments. In fact, there is a high level of concern in the province that this has always been a major risk.[115] With a renewed focus on traditional service industries such as tourism and culture and resource industries including oil and gas combined with new R&D funding programs, the province is trying to rebalance its industrial structure within the current global environment. Newfoundland's commitment strategy toward bioscience is mixed.

Did financial institutions change after the 2008 global financial crisis?

Amounts and types of financing changed after the global financial shock indicating learning by government but not as part of an overall strategy. Newfoundland established the RDC to fund pre-competitive activities such as proof of concept and prototyping but the RDC has yet to invest in any bioscience firm and its projects.[116] Firms still rely on ACOA and its innovation fund, Atlantic Innovation Fund, for R&D support.

In November 2014, much later than the other Atlantic Canadian provinces, Newfoundland agreed to commit $10 million to the pan-Atlantic Canadian regional VC fund, Build Ventures. It also created a new institution, the Newfoundland and Labrador Venture Fund with a budget of $10 million to invest in start-up Newfoundland firms. This institution is similar to New Brunswick's Innovation Fund and Nova Scotia's Innovacorp except that it has engaged a private sector fund manager, Growthworks Atlantic, with current investments in the provinces. This fund also leverages sources of finance from BDC Capital and from private individuals through the Newfoundland and

[115] Author interview, St. John's, Newfoundland, November, 2012.
[116] See:http://www.rdc.org/

Labrador Angel Network (NLAN). The decision to engage a private sector fund manager was made in reaction to NLAN's difficulties in finding lead investors to identify and quality potential investments. Newfoundland began to leverage and coordinate assets.

Creation of these new financial institutions represents a change in the way that Newfoundland frames its economic development challenges as well as solutions to them. The changes are also attempts to leverage existing and diverse financial sources in order to address each stage along the company's development from start-up through growth phase. The new financial institutions were also the result of the Newfoundland government conducting baseline studies, capturing lessons learned from neighboring jurisdictions and combining them with lessons from their own previous experiences especially in developing tax credits and other company financing schemes.

Despite these increases in settings, new programs and institutions the province still has no formal bioscience strategy. Newfoundland has made efforts to increase R&D funding in targeted industries but bioscience still relies more on federal funding with some provincial and private finance provided through FDI. Changes were largely driven by government-led policy communities.

Did skill development institutions change after the 2008 global financial crisis?

Before 2008 Newfoundland did not provide specific tax credits or funding for highly skilled technicians, scientists or managers. In 2009 RDC prioritized support to fill the skills gap and now provides up to 75% of the salary over two years of a PhD graduate in science or technology. This is a $1 million fund. But there is little indication that graduates in bioscience disciplines are benefitting. This could very well be because there are a smaller number of bioscience companies compared to Newfoundland's traditional oil, ocean technology and Arctic development.

Firms rely on Memorial University, its main vocation training center, the College of the North Atlantic (CAN), as well as graduates from other Atlantic Canadian provinces as a source of skilled labor. Training programs at CAN include Medical Laboratory Sciences, Medical Radiography, and Biomedical Electronics Engineering Technology.

These are largely designed to train laboratory technicians necessary to support research programs and clinical services directed or managed by those with PhDs and MDs.

The new RDC program, however, is not tied to securing labor from Newfoundland. Firms can source labor globally. The perennial challenge for innovative firms is how to secure the specific skills related to niche areas of marine biotechnology, bioinformatics and environmental technologies as well as managers with successful experience in commercializing new technologies.

Did corporate governance institutions change after the 2008 global financial crisis?

Biotechnology firms in Newfoundland create competencies mainly by hiring skilled individuals, collaborating with the university, NRC and customers. Some firms operate based on a "virtual" model sourcing finance in Toronto, researchers from Memorial University and independent business development and legal experts throughout Canada. Similar to New Brunswick, FDI collaborations and strategic alliances are less common, which limits knowledge spillovers necessary to grow the industry.

Firms are primarily small start-ups where the CEO is also the scientist-founder. But these few firms do have an advisory or governing board as part of their corporate structure because of provincial and federal financing rules requiring them. Such firms include Research Avenue and Semintha Nutraceuticals as well as those located in Memorial University's technology incubator, the Genesis Centre.

MNCs like Johnson and Johnson placed a regulatory affairs office in St. John's but not an R&D or manufacturing facility. While the province and individual stakeholders helped establish a BioEast, the bioscience industry association in the early 2000s, the organization was unsustainable and was folded into the more broad-based high technology industry association, Newfoundland Association of Technology Industries (NATI).

Newfoundland's fledging bioscience industry is reliant on provincial and federal R&D financing with a few exceptions. Corporate structures have been forced to change since they are coupled with government financing requirements. The intention is to create firms that are transparent and benefit from the networks of relationships that advisory and governing board members bring. It also prepares these firms for exit strategies including acquisitions by FDI. Government drove these incremental changes.

5.5.1.3 Nova Scotia

Since 2005 Nova Scotia has had no formal bioscience strategy. However, the province, ACOA and private sector have invested more in R&D than other Atlantic Canadian provinces. Individual firm strategies have led growth rather than industry in partnership with the provincial government. The industry association, BioNova, has led a weak KOST sharing information and lessons learned among its members but not creating consensus around common goals, ways of achieving them and internal competencies. Since the 2008 crisis the bioscience industry has contracted. By 2014 the province created a new way of thinking about Nova Scotia's pursuit of economic sustainability through its "OneNS" initiative. It is still unclear as to whether or not this attempt to change the province's mindset around the role of the state and private sector in facilitating economic growth will succeed.

A Weak KOST and Mixed Commitment Strategy

Unlike New Brunswick, Newfoundland and Prince Edward Island, Nova Scotia has traditionally favored an individual firm-based industrial development strategy. It has no formal, written bioscience strategy. This is despite benefiting from both provincial and federal R&D and commercialization programs and technology incubators including, the BioScience Enterprise Center, InnovaCorp's VC fund and ACOA's Atlantic Innovation fund. The accepted norms centered around individual firms developing their own growth strategies and taking advantage of government financial, technical and infrastructure-related resources.

Before 2008 the private sector comprised the majority of R&D spending at 100 million dollars even though four firms produced 85% of total sector sales (BioNova, 2007). By 2014 the number of core biotechnology firms in Nova Scotia declined to 41.

This contraction occurred after a seven year growth period from 2002-2009 where the number increased from 28 to 50.[117] The decline could be explained by the fact that bioscience firms in Nova Scotia were more exposed than firms in the other three provinces to global risk finance and markets. However, it questions whether previous forms of governance are becoming outdated and incapable of meeting industry needs.

By June 2014 Nova Scotia engaged in a highly disruptive social learning process built around the idea of "Collective Impact."[118] This new approach highlighted a major impediment that needed to be overcome: a lack of vision and commitment to economic growth. The province framed the debate within a "now or never" call to develop a new approach to old problems, acknowledging that previous strategies have failed. Leaders across sectors, within government and the university claim that a fundamental change in society is required. These leaders will first address concepts such as respect, trust in institutions and individuals, and avoidance of "parochial" and partisan interests.[119]

Coupled with major changes in attitudes is the call for more innovative ideas and different ways of thinking about the role of government and society. The new model centers around three concepts: attitude, people and economic growth. These ideas are profound and get at the heart of cultural norms rather than simply formal rules constraining the roles of government, industry and the university.

Government acknowledged the need to reevaluate its role while industry is to lead the province's economic growth. To do so, the province coordinated an independent commission known as the oneNS Commission that builds on previous efforts to evaluate its economic development programs and recommend changes. Similar to Prince Edward Island and even Ontario and Quebec the province created a working group, the oneNS Coalition, to design work plans in the three areas discussed above. The province argues that a collective response is necessary since the challenge of sustained economic growth under the current context is highly complex.

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[117] Based on BioNova membership of core biotech firms and NS Biotechnology Asset Maps. Note that not all biotechnology firms are BioNova members. However, the core group of firms are.
[118] See: http://onens.ca/about/our-work/a-new-approach-to-old-problems/
[119] See: http://onens.ca/about/

The current commission is comprised of 15 community leaders from different industries, labor, university and elected government officials including the Premier. It concluded that government should create the environment for business to succeed and address the needs of industry without controlling the process. Michel Samson, Minister of Economic and Rural Development and Tourism stated that:

> Politicians should not be picking winners and losers in the economy. Instead, government will focus on broader economic objectives, like workforce, sector and regional development, as well as having the right policies, laws, and accountability measures to foster private-sector growth. ("Private Sector to Lead Economic Growth," 2014, p. 1)

This statement at first appears no different than previous approaches and understandings of the role of government and industry in Nova Scotia. However, a deeper analysis uncovers a call for more social learning among stakeholders and collective understanding of and commitment to the province's goals. To this end, the oneNS Commission recommended improved planning and decision-making in relation to investments of money, time and expertise in pursuit of economic growth.

The specific roles of government and industry must change enough to be able to govern effectively. For example, the provincial government first must develop the capability to understand complex industries like bioscience by employing industry experts with deep business experience to quickly and effectively evaluate industries and specific business cases for investment. Transitioning to a "learning economy" also requires the *capability* to learn. This involves creating specific learning structures and mechanisms that encourage competency-building through knowledge-sharing and skills development among a broader range of stakeholders. Sufficient incentives to participate in, for example, pre-competitive collaboration projects, as well as monitoring and evaluation are necessary. This approach is not designed to take the place of individual firm strategy but to coordinate in areas of unusually high complexity and uncertainty.

Industry takes a similar perspective. BioNova's approach is to assist all members achieve their goals rather than "picking winners." The latter strategy would require dedicating all resources around those few firms with the highest potential to bring ideas to market especially since the collective understanding is that only one in 10 will succeed. BioNova has long resisted NS government efforts to lead a specific industrial strategy around bioscience and the association shares this view about not only the role of government but the industry association:

> If you're not comfortable with government picking winners and losers, just imagine having us trying our hand at it![120]

Nova Scotia's approach to growing its bioscience industry continues to emphasize individual firm strategies as drivers with government creating an effective business environment and the peak association providing support.

Did financial institutions change after the 2008 global financial crisis?

Even though NS records the highest level of R&D spending both in the public and private sectors, federal ACOA funding through the AIF program decreased during this period. VC funding increased and by 2014 nine of the 31 companies that InNOVACorp invested in or about 30% were bioscience-related. These statistics contrast greatly with New Brunswick and Newfoundland where government VC investment is weak to non-existent. Investments ranged from genomics to health IT to medical devices.[121] Provincial funding of R&D increasingly favors the commercialization-stage.

Institutional and organizational roles are changing under the oneNS Commission strategy. Nova Scotia Business Inc. (NSBI) will continue to administer the Capital Investment Rebate and the Small Business Development Program. This program provides funding directly to firms that reinvest in Nova Scotia. However, the government made two changes: Decision-making regarding investment awards will be more arms-length and only firms that co-invest along with government are eligible. The province expects

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[120] See http://bionova.ca/2013/10/small-business-week/
[121] See: https://innovacorp.ca/companies/investment

that the arms-length decision-making rule will ensure investments will be made based on business principles rather than on political interests.[122]

Did skill development institutions change after the 2008 global financial crisis?

Between 2007 and 2013 Nova Scotia continued its 15 percent R&D tax credit to support the hiring and training of scientists, technicians and researchers within bioscience firms. There were few if any changes in settings. In terms of university capacity to supply the needed labor, in 2007 the focus was more on training technicians and patent lawyers at the Nova Scotia Community College, the University of Cape Breton, and Dalhousie University law school. While technicians and lawyers are crucial to the industry, there is no biotechnology-focused MBA program-producing graduates with both a science and business background required to facilitate the commercialization process.

By 2008 the province began to address the skills gap to increase productivity and innovation by creating new skill formation and training programs. These included the Workplace Innovation and Productivity Skills Incentive (WIPSI), which provides grants to individual organizations to train staff. In addition, the Productivity and Innovation Vouchers program provides financial support to SMEs to acquire technical assistance from Nova Scotia universities and colleges. These programs combine with existing ones including the federal IRAP and SR&ED. This new approach couples finance with skills development institutions.

Did corporate governance institutions change after the 2008 global financial crisis?

Many Nova Scotia's firms are small but well-established. Firms export and out-license more since just over half are medical technology and device companies developing diagnostic kits. These small firms as well as larger pharmaceutical companies such as Novartis Pharmaceuticals Canada Inc. and Sanofi, the CROs and bioproducts company, Acadian Seaplants, Inc., have developed competencies and corporate structures

[122] See: http://novascotia.ca/news/release/?id=20140717003

reflecting more mature firms. Yet Nova Scotia has not created new firms except in the areas of nutraceuicals and imaging technologies.

Few changes in corporate structure occurred after 2007 since several core firms were established in the 1980s and 1990s. Similar to the other Atlantic provinces, start-up firms receiving ACOA R&D grant funding were required to establish either a Scientific Advisory Board or a Board of Directors. However, a review of each company's website and previous research reveals greater global collaborations between single Nova Scotia firms and partners abroad as opposed to formal alliances among local firms (Rosson & McLarney, 2004). The lack of local knowledge spillovers is still a weakness.

This trend, while difficult to attribute as a direct response to the global financial crisis, does shed light on the fact that individual firms are unable to address the complexity and uncertainty of the R&D process alone. Firms are balancing individual strategies with project collaboration among global partners with R&D support from government and the universities.

5.5.1.4 Prince Edward Island

PEI maintained its high, holistic commitment to its growing bioscience industry after the 2008 global financial crisis. It established a strong KOST in 2005 led by the industry association, PEI BioAlliance, which continues to act as industry catalyst in partnership with government. The KOST mobilized support for a niche strategy to develop bioactives products for human and animal health. It learned how to closely link sources of finance with bioscience skills and corporate competencies to achieve its goals. In addition to a strong KOST other factors such as an abundance of agricultural and marine resources, national support institutions such as ACOA, SR&ED and IRAP funding, the NRC's Institute for Nutrisciences and Health (NRC-INH), FoodTech Canada, and the leadership of prominent elected and non-elected individuals helped to maintain high levels of commitment to the niche strategy.

A Strong KOST and High, Holistic Commitment Strategy

Prior to the global financial crisis PEI aggressively began to develop and implement a bioscience industrial strategy addressing much needed finance, skills and corporate competencies. The structure and nature of the industry includes entrepreneurial companies and FDI firms such as Novartis, Genzyme, OmniActive and Sekisui developing bioactives for human and animal therapies. Michael Mayne, former Deputy Minister for Advanced Learning and Lead Scientist for NRC-INH , in 1999 Initiated by, followed by Rory Francis, head of the PEI BioAlliance, these individuals mobilized support for the new strategy by creating a strong KOST. The specific bioscience strategy fit within the provinces' overall strategy to transition towards a knowledge economy.

Immediately after the 2008 global financial crisis the PEI government produced a new industrial policy, "Island Prosperity – A Focus for Change." This strategy allocated $200m to help facilitate four key sectors including bioscience, ICT, aerospace and energy. The bioscience goals were to increase sales to $300m, raise fulltime employment to 2,000, and improve the PEI brand globally as a national center for excellence in natural bioactive-based health and nutrition product development.

In the new strategy Premier Robert Ghiz acknowledged that traditional industries underpin and drive knowledge-based ones:

> Our traditional industries and our new industries are not two separate worlds…Our bioscience sector is creating innovative, competitive value chains extending from the fields, forests and sea to highly sophisticated food and health products. (Francis, 2010)

As part of the Island Prosperity framework the bioscience strategy and work plan have been reevaluated every three years since 2005. The latest review was in 2012 and extends the strategy through 2015. This process was delegated by the government to the industry association, the PEI BioAlliance, which receives funding from both the provincial government and member organizations. This peak association continues to lead deliberations among stakeholder groups including individual biotech firms, FDI, provincial and national research institutes, university researchers and those from traditional industry trying to make the transition. The association articulated industry's strategy whose members and the government collectively agreed to focus on bioactives (BioAlliance, 2012).

The association and its Board of Directors comprised of these diverse stakeholders meet quarterly to monitor and evaluate strategic goals. The process provides a "trusted space" for community dialogue designed to find common ground among conflicting interests. Every three years it "assesses the current state, clarifies vision and mission, sets goals, and aligns strategies and priorities to achieve that vision" (BioAlliance, 2012, p. 2).

Unlike other provinces, the governance process is highly inclusive, encouraging social learning. Not only does the KOST regularly review previous goals and tactics, it combines this knowledge with new knowledge generated by its membership and committees tasked with monitoring the industry. The federal and provincial governments have supported the strategy despite changes in power emphasizing "alignment" of interests, leadership and focus (BioAlliance, 2012). Sustained commitment to the strategy separates the province from other jurisdictions and is an important factor explaining the industry's relative success to date.

I argue that with this sustained high level of commitment PEI's bioscience cluster is emerging rapidly. Survey data from a collaborative study as well as reviews by the PEI BioAlliance reveals that the total number of bioscience firms increased from 30 to 35 between 2009 and 2013 representing a 17% increase (Alleva-Caceres, 2014) . The network of relationships among the growing number of organizations has become dense and more firms have developed relationships with global partners. But firms still generate most revenue from government R&D.

Did financial institutions change after the 2008 global financial crisis?

R&D finance levels and programs changed after the 2008 global financial crisis. Federal and provincial R&D funding for PEI universities are more than twice as much than the other Atlantic Canadian provinces. PEI increasingly leverages private investment and combined they increased 40% between 2004 and 2011. However, ACOA federal funding decreased from 11.75 million in 2007 to 10.16 in 2013. These data indicate that PEI is the fastest growing province when it comes to provincial and private sector R&D

funding. But it is possible that federal budgets were negatively affected by the global financial crisis.

PEI created new financing programs. These included the Discovery and Development Fund seeding high risk, commercialization-focused projects as well as provincial-NRC partnerships that finance specific collaboration projects between local firms and the NRC. In addition, PEI firms are increasingly developing financial relationships with non-local customers and R&D partners. These programs combine with the new Bioscience Tax Incentives that are offered to PEI biotechnology start-up firms.[123]

Shocks like the 2008 global financial crisis affect small, young bioscience clusters less than their larger established counterparts since they are relatively insulated from risk capital such as VCs that are normally required to commercialize biotechnologies. PEI is gradually shifting from government R&D grants disbursed directly to individual firms to co-financing of public-private collaboration projects. PEI firms are increasingly securing private global sources of finance that they use to leverage public sector funds especially from ACOA (Alleva-Caceres, 2014).

Did skill development institutions change after the 2008 global financial crisis?

Since 2008 PEI has made changes in its programs supporting skill development. In 2010 it created a new MBA program in Biotech Management at UPEI and a two year Bioscience Technology Program at its technical college, the Holland College Centre for Labour Force Innovation. The province also conducted a review of its Provincial Immigration Policy creating more favorable terms for firms to hire skilled individuals from abroad. PEI bioscience firms are increasingly hiring and retaining scientists from China, India and Europe to fill niche areas from fish vaccine research to software design for medical devices.[124]

By 2012 incremental changes continued with a new training program to develop specialists in quality control and regulatory affairs. Both programs are needed to help

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[123]Sources include provincial industrial and sectoral strategy documents; For government R&D spending - CIHR, NSERC and CFI in NATI report; AIF evaluation by author; annual reports.
[124] Author interview, Charlottetown, Prince Edward Island, June, 2014.

facilitate drug and medical device approvals in Canada and globally. During the same year the province instituted a specialized labor tax credit on personal income that was designed to help firms hire and train scientists and specialized managers.[125]

General employment within the PEI bioscience cluster grew by about 44% from 455 to 655 since 2009. The province has made significant progress in creating highly skilled jobs. The number of scientist positions held mainly by PhDs has more than doubled. Sales, marketing and quality control positions increased by 47% but technicians declined by close to half. Non-local scientists increasingly fill Ph.D. positions while local universities supply technicians (Alleva Caceres, 2014).

PEI called for a province-wide human resources development strategy in collaboration with federal agencies to sustain its competitive advantage. The change in approach from individual organizational policies toward a more coordinative and comprehensive strategy should enable the province to leverage resources in support of its explicit goal: creating and attracting highly skilled labor for growth industries. Its previous policy relied on providing unemployment benefits to existing labor in more traditional industries.[126]

Did corporate governance institutions change after the 2008 global financial crisis?

PEI firms have created competencies both internally through a change in structure and through external ties with customers, suppliers, R&D partners, the industry association, provincial and federal governments and the university. Corporate structures changed to include either a scientific advisory board or a governing board. In 2009 no locally owned firm had instituted any type of board but by 2013 almost all had (Alleva Caceres, 2014). It is plausible that firms were responding to ACOA requirements before receiving federal financing through its Atlantic Innovation Fund.

Scientific boards can help young firms evaluate potential therapies and products while governing boards can secure financing from outside sources, access global networks of contacts to create markets, and provide legitimacy to a start-up. A successful

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[125] Ibid.
[126] Ibid.

entrepreneur is often asked to become a member of a start-up's board in the hopes of creating knowledge-spillovers and as a signal to potential acquisition partners.

Survey data comparing the nature of relationships and how they changed from 2009 to 2013 indicates that individual firms are increasingly commercializing their products, services and technologies. Ties among PEI firms and between local and non-local firms, mostly customers and suppliers, increased 85% during this period (Alleva Caceres, 2014). R&D relationships increased 10% between PEI firms and private sector organizations and by a similar amount with public research institutes. These figures indicate that R&D is still conducted primarily in-house but firms are increasingly engaging in more collaborative projects locally, within Canada and globally (Alleva Caceres, 2014).

While formal strategies and related goals have changed incrementally since 2008, firm behavior has changed in terms of how they learn and manage growth. In the past, the provincial government created expectations that it would provide R&D grants directly to firms and the university. Formal rules and social norms have changed in support of partnerships and collaboration projects that leverage public and private sector finance.

PEI's decision in late 1999 to transition to a knowledge-based economy led to the creation of a strong KOST in 2005. This team combined with the island's small size and agricultural and marine resources have created a path dependent trajectory toward bioscience industry growth despite changes in governments. The industry-led KOST in partnership with government sees its role as a "catalytic coordinator" and "innovation intermediary" aligning vision, setting priorities, and allocating resources to achieve bioscience industry goals (Francis, 2012, pp. 20-21). This process created and improved institutional complementarities in finance, skills development and corporate governance before, during and after the 2008 global financial crisis. PEI created this holistic strategy by shifting paradigms that traditionally favored government-led policies to industry leadership with public sector financial support.

5.6 Conclusions

5.6.1 Empirical Findings

All four provinces have invested in R&D and attempted to diversify and coordinate financial sources. These include tax credits, grants and government-funded and in some cases privately managed VC funds such as in Newfoundland and New Brunswick. But not all new sources are designated to bioscience firms. Most are designed to support high-tech firms generally across sectors such as ICT, clean technologies, biotechnologies, geology, oil and gas.

Firms rate highly federal funding such as the AIF and the IRAP. But access to these programs was difficult due to bureaucracy and lack of awareness. In addition, the public and private sectors invest in R&D but at different levels depending upon the province. For example, Nova Scotia's private sector accounts for 65% of overall R&D spending. In Prince Edward Island government still funds a significant amount of R&D even though product sales and angel investments are increasingly a source of individual firm revenue. The continued reliance across regions on federal and provincial R&D capital raises the question as to the sustainability of these bioscience clusters. Will provinces assume that some government role and funding is necessary over the long-term? After 2008 is the role of government changing significantly as it increasingly embeds itself in networks and industry-specific processes?

Provinces differ in their skill development strategies. New Brunswick continues to channel support for university research. However, the province's strategy to finance bioscience Chairs at the university requires university-industry collaboration on specific projects. While Newfoundland established a new program to cover a significant portion of recent PhD salaries, helping to offset costs to local firms, there is little evidence that bioscience firms have benefited. Competing industries in oil, geology and clean technologies appear to take advantage of the new scheme. Finally, recent strategies announced by provincial governments in Nova Scotia and PEI indicate a rethinking of skills needs at a much more disruptive level. The new approaches call for province-wide human resources strategies across industries in order to identify and fill gaps.

Corporate governance structures and competencies are slowly changing. ACOA and provincial funding agencies now require that companies applying for financing establish an advisory or governing board. Many local firms do not begin with the necessary management competencies and networks required for corporate growth since they are spin-offs from university research. Norms related to R&D and commercialization strategies are also changing. In Prince Edward Island firms are increasingly developing commercialization ties with both local and non-local customers, R&D and technical partners as opposed to relying solely on government R&D grants, though still quite a few firms do. Even in this case, government is increasingly requiring firms to secure a private sector financial partner in order to leverage federal ACOA and provincial sources of funds.

The nature of economic governance in Atlantic Canada is also changing. Federal and provincial governments generally coordinate their financial and services support for economic development to avoid duplication. But unlike Quebec and Ontario, Atlantic Canadian provinces have difficulty aligning their niche bioscience interests and small discoveries with federal strategies emphasizing big discoveries and applications.

The role of government is changing as well from arms-length decision-making to embeddedness in the strategy process along with the private sector and universities. This change is evident in Prince Edward Island in the most pronounced way as government partially funds the formal bioscience network, PEI BioAlliance led by industry. This network acts as "catalytic coordinator" of the industry with its multi-stakeholder membership. The nature of embeddedness is different in the other provinces where government leads the process as it interacts with the private sector.

5.6.2 Theoretical Findings

The evidence from aspiring bioscience provinces supports *hypo 1* and *2* but not *hypo 3*.

Prince Edward Island is the smallest of the provinces and represents a *least likely case*. In 2005 before the global financial crisis the province created a strong KOST led by the industry association, PEI BioAlliance, in partnership with government at all levels, individual firms, the University of Prince Edward Island and PROs. The KOST mobilized stakeholders around a common strategy focusing on bioactives and created and changed institutions in support of it.

The strategy was industry-led with government as a financial partner. It involved new infrastructure, increased financial support, creation of university degrees programs, and an improved business environment for FDI. But firms were start-ups tied to government R&D financing and collaborations were rare. Up to and after the 2008 financial crisis the KOST strengthened, the number and diversity of firms increased, their competencies improved and the cluster increased its international ties. These changes created opportunities among KOST participants to regularly deliberate existing strategy, new tactics, goals and to adjust in light of this new knowledge. The efforts positioned Prince Edward Island to pursue a holistic, high commitment strategy that withstood the 2008 global financial crisis.

Nova Scotia, the largest of the provinces, maintained a weak KOST leading to a mixed commitment strategy both before and after the financial crisis. The province's individual firm-level strategies continue to lead its bioscience industry. Neither New Brunswick nor Newfoundland created a KOST and few if any policy communities existed before the crisis resulting in a low commitment strategy. But bioscience clusters were developing in niche areas including plant science, aquaculture, bioinformatics and marine science. After the crisis, policy communities evolved in both provinces drawing attention to the economic and health benefits of bioscience creating mixed levels of commitment.

The provinces' bioscience industries did not contract immediately after the global financial crisis as they did in Quebec and Ontario but changes occurred. The number of bioscience firms declined in Nova Scotia while they grew in PEI. I argue that the presence and strength of a KOST played a significant role.

The Atlantic Canadian provinces compared to Quebec and Ontario were less tied to global sources of risk finance including VCs and pharmaceutical firms. Were these small, rural provinces responding to the global financial crisis or simply pursuing path dependent trajectories and making incremental changes to their commitment strategies? Most provinces still rely on government funded R&D with the possible exception of Nova Scotia. However, local public-private VCs, angel investors and large global customers are increasingly financing R&D and commercialization activities in Atlantic Canada.

Other explanations interact to impact commitment strategy levels and changes. Different natural resources within each province defined their core bioscience competencies from bioactives to bioinformatics to marine biotechnology. These resources shaped commitment strategies in all four provinces involving finance, skill development and corporate governance as provinces developed baseline studies and bioscience asset maps from which to develop strategies.

Rival industries competed for resources. However, provinces like PEI reframed the debate claiming that traditional industries like agriculture provide a platform to develop knowledge-based industries like nutraceuticals. Finally, each province has access to the same national financial institutions including the Atlantic Canada Opportunities Agency (ACOA), IRAP and SR&ED R&D funding. PEI firms and research organizations are more aggressive in applying for and securing this finance compared to the other three provinces.[127]

5.6.2.1 Potential Variables Affecting Bioscience Industry Performance

The study revealed important variables for future research. These omitted variables include:

- The nature of networks and clusters;
- Disconnectedness from global risk finance;
- Lack of receptor capacity and economies of scale;
- Federal – regional misalignment of strategic interests;
- Policy discontinuities from one government to the next;
- Lack of public awareness;
- Lack of "patient" capital; and
- Weak labor markets.

[127] Based on an analysis of ACOA contract awards since 2006.

Some explain levels of and changes in commitment strategies. However, those explanations such as the misalignment of multi-level governmental agency strategies and policy discontinuities are accommodated by the definition of different types of KOSTs.

The nature of networks differs depending upon the province. PEI demonstrates "small world" network characteristics where the majority of its 35 firms and support institutions are formally connected. By 2013 PEI's network had begun to internationalize and had increased its density of ties locally. This presages high levels of learning given the ease with which participants were able to share information and knowledge creating trust. The local, strong KOST led by the PEI BioAlliance since 2005 drove the process. PEI stakeholders and their neighbors in Nova Scotia and New Brunswick recognized the role of the KOST in sustaining this is positive trend.[128] However, a heavier reliance on government grants and contracts is still a challenge.

Nova Scotia was not considered to be a full-fledged cluster since its participants did not rely on the local market for customers and suppliers (Rosson, 2003). The industry does not consider itself a "cluster."[129] With 50 firms plus support institutions, bioscience is seen as firm-led, not government "choosing industrial winners" and forcing firms to behave according to a dominant, government-led strategy.[130] Bioscience is "entrepreneur-driven, not curiosity driven" and responds to "market pull."[131] Hence, a variety of individual corporate strategies ranging broadly from "home-grown" approaches to FDI and mergers and acquisitions drive growth. Despite the individual strategies high levels of trust among firms exists and has helped the industry to grow.[132]

Rosson and McLarney's research reveals that Nova Scotia's industry is networked locally and globally through finance and supplier relationships (Rosson & McLarney, 2004). While anchor firms and individual researchers are relatively more connected globally, the vast majority of firms, most of which are small, do not have the capabilities to reach beyond their own provinces and sometimes beyond the firm's boundaries.

[128]Author interview, Fredericton, New Brunswick and Halifax, Nova Scotia, July, 2010.
[129]Author interview, Halifax, Nova Scotia, July, 2010.
[130]Author interview, Halifax, Nova Scotia, July, 2010.
[131]Author interview, Halifax, Nova Scotia, July, 2010.
[132]Author interview, Fredericton, New Brunswick, July, 2010.

However, third parties such as bioscience industry associations help fill this gap by enabling access to information, knowledge and international contacts.

The region's ability to protect itself from the negative effects of the financial crisis is due largely to the fact that it was not as connected in the first place to external sources of funding. Rather, firms rely primarily on domestic sources even though we see this changing as lead local firms have become more sophisticated in leveraging local public sources with private global ones.

The region faces many challenges despite the above positive characteristics. The lack of receptor capacity is a major weakness in small markets like those in Atlantic Canada. One interviewee in New Brunswick praised the relative success in increasing the number of new bioscience firms over the last decade but lamented that the province and the region was "research rich, innovation poor."[133] Most technology is licensed out rather than developed and manufactured in the region and exported as new products.[134]

The lack of scale and the great diversity of small, niche bioscience activities that are somewhat disconnected among each other depending upon the province is another difficulty. One executive in Nova Scotia noted, "we have everything from soup to nuts."[135] It is difficult to develop a strategy meeting the needs of the entire bioscience industry. Nutraceutical manufacturers will require different resources and incentives compared to pharmaceutical developers or CROs given the divergent nature of their technologies, processes, products and services.

Inter-niche learning is beginning to address the situation. Industry and government in New Brunswick did not discount the possibility of knowledge sharing between potato and aquaculture R&D. Despite some knowledge-sharing, bioscience is still disconnected. This condition presents a challenge to policy-makers. Is it more effective to choose leading niches demonstrating the highest promise for successful innovation and growth? Since markets for new products do not yet exist, how do governments and industry stakeholders measure uncertainty and risk in order to select growth industries? Is it

[133] Author interview, Fredericton, New Brunswick, July, 2010.
[134] Author interview, Fredericton, New Brunswick, November 2011.
[135] Author interview, Halifax, Nova Scotia, July, 2010.

politically possible to consider an Atlantic Canada-wide bioscience strategy in the hopes of creating a regional, collective strategic intent and economies of scale?

National – regional political misalignment presents another regional challenge. According to one interviewee and corroborated by others, Atlantic Canada is considered “a bit of an annoyance” by the federal government, which sees the region and its bioscience industry, particularly agricultural biotechnology, as “artisanal.”[136] Western Canadian provinces, Ontario, Quebec and Agriculture Canada continue to shape national agriculture and agricultural biotechnology strategy. These policies establish how financial, technical and infrastructure resources are distributed. The Atlantic provinces must focus on niches and long-term return on investment.

While there may be strategic misalignment in agricultural biotechnology, provinces benefit from the NRC Centers of Excellence. Nova Scotia houses the new center for research, diagnosis and treatment of brain disorders. There is also evidence that the federal government is beginning to let the provinces lead with their own bioscience strategy.[137]

Political discontinuities also affect the sustainability of previous bioscience strategies and ultimately industry growth. “As governments change, policies change” lamented one interviewee.[138] Each Premier brings his or her own policies to bear on economic development. Selecting “high road” versus “low road” policies, in other words the choice between dedicating resources to knowledge versus traditional industries is highly susceptible to the political process.

Agriculture and the fisheries are traditional constituents in each province and Premiers are often forced to choose between these and knowledge industries promising longer return on investment though with highly uncertain prospects. Often a hybrid strategy is pursued. With a public unaware of the benefits of dedicating government resources to bioscience, political parties in power tend to either support the industry and are now engaging in public awareness-raising efforts, or, there is a fear that this support

[136]Author interview, Fredericton, New Brunswick, July, 2010.
[137]Author interview, St. John’s, Newfoundland, November, 2012.
[138]Author interview, Fredericton, New Brunswick, July, 2010.

may not last. These contingencies depend upon each province, their election cycles and the individual Premiere who may or may not share the long-term visions of his or her predecessor. Elected politicians may choose to discard policies established under previous leadership in order to implement his or her own values and vision. Industry leaders must lobby both political parties in order to affect political continuity in support of a longer-term bioscience strategy. Looming elections still threaten to stall progress right at the moment when the region is beginning mobilize stakeholders in the form of policy communities and KOSTs.

While the region increasingly accepts the economic argument for investing in knowledge industries resulting in higher paying jobs as well as new and sustained company growth policy-makers face political challenges from primary industries including agriculture. For example, bioscience is defined by a boundary such that potato farmers will not be "saved" by R&D and innovation in bioscience. The two industries are separate and distinct. However, the Potato Institute in New Brunswick is highly innovative producing several varietals each year and spinning-off over 70 companies with specific capabilities. The R&D developed at the institute may be shared with bioscience niches to develop and commercialize new, non-potato related products. Farmers, a strong, traditional constituency benefit less from resources dedicated to bioscience.

The regional financial market has been weak until recently with the establishment of pre-competitive and seed financing, public-private VC funds, angel investors, and partner firm financing. Local banks maintain strong relations with anchor firms but they lack the knowledge to assist small science-based firms. Other institutions such as the Community Business Development Corporations help to fill the financing gap through seed capital, low-cost loans and guarantees. Local strengthening of financial institutions help to offset the probability that global VCs will remain reluctant to invest in Canada let alone Atlantic Canada. Since the 2008 global financial crisis the U.S. VC industry has signaled that there will be “no new VC funding coming from the U.S. to Canada” in the near future.[139]

Weak labor markets in specialized areas of regulatory approvals, management of commercialization processes, and research directors exist but it is not difficult to find qualified technicians. Strong local technical institutions combined with weak global networks help explain this outcome. By 2013 PEI and NS had expanded global ties and individual firms began to learn how to successfully recruit skilled labor within shorter time-frames (Alleva-Caceres, 2014; S. Casper, Krause J., MacNevin A., 2010)

[139] Author interview, Quebec City, Quebec, October, 2012.

CHAPTER 6

CONCLUSION: TOWARD LEARNING ECONOMIES?

6.1 Summary of Findings

Countries and regions within them that “learn-to-learn” are better able to transition to knowledge-based industrial growth. The learning structures they create break down silos, leverage resources, share knowledge and create competencies to help sustain high level bioscience commitment strategies especially in the face of global shocks such as the 2008 global financial crises. Those that rely on past approaches involving fragmented policy communities struggle to adapt.

The most significant finding of this research is that those Canadian provinces that established a strong knowledge-oriented strategy team (KOST) *prior to* the 2008 global financial crisis “puzzled and powered through” to maintain high level commitments to their bioscience industries afterwards. I use empirical evidence from the six case studies to evaluate the three hypotheses presented in chapter one.

Hypothesis 1: A strong KOST in place prior to a global financial crisis is likely to maintains a high commitment strategy afterwards.

Quebec and PEI cases support this hypothesis. The prevailing social norm in Quebec valued government intervention through industrial policies. In the 1980s the province took a strategic approach towards developing its bioscience industry. This experience provided the platform to construct strong KOSTS in Montreal, Quebec City and Sherbrooke prior to the 2008 global financial crisis. After the crisis BioQuebec and the Ministry of Economy, Innovation and Export helped to facilitate a meta-network of KOSTS across the major bioscience industry clusters. Organizations within the network took a hybrid approach by participating in the province’s new bioscience strategy while continuing to design and implement their individual strategies.

The presence of a strong KOST does not always immediately prevent significant fluctuations in industry performance after a global financial crisis. But it did help Quebec quickly respond to these shocks by learning about new opportunities and threats, creating consensus around new overarching goals, and adjusting tactics to reach them. The result is a strategy that connects changes in finance, skills and corporate governance institutions into a holistic commitment strategy.

Small, rural provinces like PEI with a strong KOST led by its bioscience network organization, PEI BioAlliance, prior to the 2008 global financial crisis also maintained a high, holistic commitment strategy. The Atlantic Canadian provinces are less connected to global sources of risk finance shielding them from a sudden scarcity of funding. But they suffer from lack of skilled labor, lower productivity and income levels and knowledge spillovers. Despite these obstacles PEI, the smallest of these provinces, continues to grow its bioscience industry.

Hypothesis 2: A weak KOST in place prior to a global financial crisis is likely to maintain a mixed commitment strategy afterwards.

Ontario and Nova Scotia cases support this hypothesis. Ontario shifted from a weak KOST led by its industry association before the 2008 global financial crisis to fragmented policy communities afterwards as the province struggled to adjust. New policy communities including a second industry association competed over resources and goals. These dynamics maintained a mixed level of commitment and prevented institutional complementarities among finance, skills and corporate governance. Ontario suffers from old industrial structures framed within a "states versus markets" mindset applied to bioscience. However, the province is beginning to signal a change in mindset as it acknowledges the need for public-private partnerships to address the inherent market failures in bioscience.

Nova Scotia pursed a similar path. The province maintained a weak KOST and mixed levels of commitment to its bioscience industry before and after the 2008 global financial crisis. Since 2005 the province has not developed a significant strategy despite success in the late 1990s in mobilizing resources and consensus around bioscience. Nova Scotia's individual firms and their networks have generated their own commitments with an explicit understanding that neither government nor industry should “pick winners”. The public-private VC fund is active in investing in local bioscience firms. But without a strategic approach involving social learning among bioscience organizations as part of individual firm strategies, I argue that Nova Scotia’s performance has suffered since the 2008 financial crisis as the number of firms has decreased.[140]

Hypothesis 3: When no KOST is present prior to a global financial crisis a low commitment strategy is likely to persist afterwards.

No cases support this hypothesis. Neither New Brunswick nor Newfoundland created a KOST and few if any policy communities existed before the crisis resulting in a low commitment strategy. However, after the crisis policy communities evolved in both provinces drawing attention to the economic and health benefits of bioscience creating mixed levels of commitment. Incremental social learning occurred within these communities but not among them because of competing interests. Newfoundland developed its niche in bioinformatics and marine biotechnology while New Brunswick reinforced its efforts to mobilize its bioscience sector by increasing funding in BioNB, its lead bioscience agency. Major changes in these provinces were the result of newly elected governments and university-industry collaboration, not industry-led.

The results of the case studies demonstrate the significance that a strong KOST plays in creating and sustaining bioscience commitments. Without one, regions within countries either continue along a negative path dependent trajectory, or, they make incremental changes leading to slightly higher commitment levels. However, it is plausible that this latter approach will become less effective as global competition heightens and rapid innovations in biotechnology continue. A strong KOST brings the necessary mindset and built-in learning mechanisms that inform strategic process

[140] According to data from Nova Scotia’s industry association, BioNova, the number of members has decreased from 50 to 41. This data may not include all bioscience firms in the province but does include its core.

management. It enables regular monitoring and evaluation of industry goals and changes in them. These changes can occur in light of new information gleaned from reviews of current and previous strategies as well as from global bioscience trends including innovations and competitor analysis. The competencies of the strong KOST and its participants improve and sustain as this process ensues. They are not lost when new governments are elected or new policy groups arise.

The table below matches empirical evidence from the cases with the independent and dependent variables.

Table 14 Case Study Results

	IV		Varying Characteristic of KOST		Varying Characteristic of KOST		DV		
	KOST/Policy Communities		**Social Learning**		**Iterative Bargaining**		**Commitment Strategy** (Finance, Skill Development, Corporate Governance)		
	Pre-2008	**Post – 2008**	**Pre-2008**	**Post – 2008**	**Pre-2008**	**Post – 2008**	**Pre-2008**	**Post – 2008**	**Change**
Prince Edward Island	Strong	Strong	Incremental	Disruptive	Coordinated	Coordinated	High	**High/Holistic**	+
Quebec	Strong (beginning 1980s)	Strong	Disruptive	Disruptive	Coordinated	Coordinated	High	**High/Holistic**	+
Ontario	Weak	Policy Communities	Incremental	Disruptive	Coordinated	Fragmented	Mixed	**Mixed**	0
Nova Scotia	Weak	Weak	Incremental	Incremental	Fragmented	Coordinated	Mixed	**Mixed**	0
New Brunswick	None (Few if any policy communities)	Policy Communities	Incremental	Incremental	Fragmented	Fragmented	Low	**Mixed**	+
Newfoundland	None (Few if any policy communities)	Policy Communities	Incremental	Incremental	Fragmented	Fragmented	Low	**Mixed**	+

Note: The indicators represent both the level of commitment and a change in direction and type.

231

Why do similar regions within countries pursue different bioscience commitment strategies?

The research reveals a significant role that a knowledge-oriented strategy team (KOST) plays in constructing and sustaining commitments to bioscience. Using a most similar systems approach to compare the two large, industrialized provinces of Quebec and Ontario and separately the four small, rural provinces of Atlantic Canada helped to highlight this variable. In addition to the strength of a KOST and multiple policy communities, other variables help explain different levels of and changes in commitment strategies. Natural resources, rival industries, province size and national institutions also interact with a KOST to influence the strategy.

Natural resources underpin where R&D will be invested, new degree and training programs as well as firms' core competencies. It helps understand why Newfoundland invests in bioinformatics with its founder population as a base, why Prince Edward Island invests in bioactives with its agricultural and marine resources and why Quebec invests more broadly in human genomics given its excellence in university research. Rival industries partially explain why Newfoundland commits less to bioscience and more to its resources industries like offshore oil and gas. But it does not help explain why Prince Edward Island has been able to maintain high levels of commitment to bioscience despite other growth industries like aerospace and digital media.

The size of the province does not affect bioscience commitment levels. The likelihood of a large province like Quebec gaining consensus around common industry goals is small. Yet, its previous experience with government-industry interventions provided a platform to do so. And even though Prince Edward Island's small size and dense network of bioscience organizations has been an advantage, it has avoided the "small world" network trap where no new information is shared because of lack of network growth. Finally, national institutions like the Atlantic Canada Opportunities Agency, the SR&ED and IRAP R&D funding schemes as well as the National Centres of Excellence combine with financial and infrastructure commitments at the provincial level. Together they shape firm-level investment decisions.

A strong KOST helps firms mobilize these resources, gain consensus around a specific strategy and its goals and act as another resource for firms to improve their competencies and competitiveness. It enhances rather than replaces individual firm strategy.

Does a strong knowledge-oriented strategy team (KOST) help build and sustain a high bioscience commitment strategy?

To answer this question and fill the literature gap I created a new variable, the KOST. It builds on Hall's, Howlett and Bennett's conception of a "knowledge-oriented policy community" and Ansell's "project team" in the social learning process as they change policies (Ansell, 2000; Bennett & Howlett, 1992; P. A. Hall, 1993). The key difference lies in the role of the state, replacing policy community with strategy team and the creation of learning structures. Policy communities are typically led by the state while a strong KOST balances roles. The state provides resources while industry leads strategy development. It fuses the knowledge-focused part - accumulating and understanding previous policies, principles and practices in combination with new information, ideas and changing goals accordingly - with the team component signifying a more cohesive and deliberative approach.

A strong KOST is inclusive, flexible, deliberative and engages in disruptive social learning and coordinated bargaining processes that build competencies. It accesses the latest information and knowledge about bioscience as well as best practices through KOST learning structures. These range from members' global networks and those developed through the KOST where knowledge spillovers occur; subject matter committees tasked with conducting strengths, weaknesses, opportunities and threats analysis; routine interactions to design and implement work plans in line with industry goals; and regular monitoring and evaluations of progress.

These structures and processes affect ways of thinking about challenges and opportunities in light of new information and occur prior to the creation or changing of institutions. They facilitate information and resource-sharing among a range of participants thus increasing the number of possible solutions to the bioscience challenge.

Policy communities and a weak KOST can still learn by reviewing previous policies and changing them but they do so incrementally and bargaining processes are either fragmented or coordinated. The missing link is a systematic review of the global bioscience industry, market trends, new ways of facilitating industry growth, and changing goals in light of this new information. These governance forms may facilitate information but they do not improve competencies. Provinces can commit to one set of institutions such as R&D finance but not another such as skills development through this process.

Why do some provinces' level of commitment change in response to a global financial shock and others do not?

Scholars predict that when institutional complementarities exist, the formal and informal rules do not change leading down a path-dependent trajectory. The only time institutions change is after an external shock as interests and power positions realign to form a new equilibrium (P. A. Hall & Soskice, 2001; Morgan et al., 2010). But this research provides mixed results. Prince Edward Island and Quebec maintained high levels of commitment through the crisis and Ontario and Nova Scotia sustained mixed levels. The substance of the rules may have changed but their level of complementarity did not. Only Newfoundland and New Brunswick shifted from low to mixed commitment levels by changing their mindset around the role of R&D finance. They shifted away from government grants toward shared risk finance mechanisms. Prince Edward Island, Quebec, Ontario and Nova Scotia did not change for three reasons. First, a strong KOST in the first two provinces enabled regular monitoring of their strategies in light of the sudden scarcity of finance. Quebec reacted quickly due to its previous successful experiences in creating interventions in partnership with industry. PEI was less affected by the crisis and simply continued to implement and adjust its strategy. Ontario and Nova Scotia maintained mixed levels due to their weak KOSTs and fragmented policy communities. They struggled to gain consensus around industry goals even though competing strategy teams in Ontario like OBIO, LSO and government have separately developed their own. The provinces' tradition of framing the governance choice as states versus markets forces them to shy away from an industrial policy perceived as "picking winners." Individual firm strategies continue to underpin industry development.

How does a strong KOST develop in the first place?

While the dissertation does not address how a KOST, particularly a strong one, develops, research did uncover a pattern. A sequence of events and key individuals drive the process. First, when a new technology gains legitimacy on a global scale like biotechnology a few key individuals gather informally in a particular jurisdiction with a vested interest in adopting it, developing it further or expanding its use. This occurred in Ontario, Prince Edward Island, Nova Scotia and Newfoundland. In Ontario the Toronto Biotechnology Initiative was founded early in the 1980s by a group of researchers, lawyers, entrepreneurs and government industry and economic development specialists. The first meetings were informal sessions where participants shared information and knowledge about biotechnology and its potential use and development in the province. The other provinces even gave their informal groups a name, the "Belvedere Life Sciences Group" and the "BioNova Biotech Working Group" both founded in the early 1990s in Prince Edward Island and Nova Scotia, respectively, as well as the "Ramada Group" founded in the late 2000s in Newfoundland. These groups met not only to discuss ways in which they could take advantage of the new technology, but within the context of cultivating the provinces' competencies to sustain economic growth. These groups represent the first effort to create networks, break down silos and coordinate activities.

Second, in Ontario and Prince Edward Island the informal gatherings evolved into formal organizations while in Nova Scotia it petered out as individual firm strategy began to drive growth. And Newfoundland's group is still informal despite major achievements in establishing the necessary infrastructure to research health IT applications. The formal organization also helped to gain legitimacy as a voice for the industry to attract FDI and resources. Some established as traditional industry association like Life Science Ontario requiring membership dues in return for services such as legislative lobbying efforts, networking opportunities, and industry reports. Others like PEI created a bioscience network of organizations with the name PEI BioAlliance. This organization represents what this research considers a strong KOST.

6.2 Theoretical Contribution

This research is interdisciplinary. It draws from institutional economics, economic geography and sociology, historical institutionalism, and comparative political economy to understand institutional change after the 2008 global financial crisis. It treats institutions as commitments (D.C. North, 1990).

The dissertation helps to fill the literature gap by answering the following questions: Why do similar regions *within* countries pursue different bioscience commitment strategies? Does a strong knowledge-oriented strategy team with disruptive social learning and coordinated bargaining characteristics build a high level of commitment to bioscience? Is it sustained throughout a global financial crisis? Why do some commitment strategies change in response to a global financial shock and others do not?

These are important questions that enhance our understanding of theories of institutional change and knowledge industry development. Provinces design their own industrial strategies aligned or in parallel with federal policies yet comparative political economists focus on national level comparisons. Comparative analyses of bioscience institutions tend to be static and results are read-off existing institutions rather than dynamic, explaining why and how they were created and changed (S. Casper, 2010). What happens before and immediately after a global financial shock is unclear (Morgan et al., 2010).

While economic geographers and sociologists study structures, organizations and groups and their interaction within defined spaces, they neglect politics, social learning and modes of governance as variables. Economic geographers have extensively analyzed various factors explaining knowledge cluster emergence and sustainability. These range from a sufficient knowledge base to second generation entrepreneurs to institutional reforms. But relatively little work has examined the *processes* by which institutions are created and changed in the first place and how social learning and political interests at multiple governance levels affect them(P. Braunerhjelm & M. Feldman, 2006; S. Breznitz et al., 2010; Gertler & Vinodrai, 2009; D. Wolfe & Holbrook, 2000).

The results support previous research arguing that successful regional strategies design local institutions such as financial regulations and labor markets to fit industry-specific needs (Locke, 1995; Malerba, 2002). They do not simply implement a one-size fits all national strategy. But national level policies and global networks do have an impact (D. Breznitz, 2007; Edquist, 1997; B. Ä. Lundvall, 1992). National strategies often provide funding, technical assistance and rules governing, for example, intellectual property rights that coexist, coordinate or conflict with local institutions. Ultimately, local individuals and organizations who share similar beliefs about technology objectives make bioscience commitments (P. N. Cooke et al., 2004; Segal & Thun, 2001). Generating these similar beliefs is a central role of a strong KOST. Explanations of conflict alone in generating commitments are not sufficient as the Prince Edward Island and Quebec cases demonstrate.

A path dependence argument partially explains why Prince Edward Island, Quebec, Ontario and Nova Scotia did not change their bioscience commitment levels after the 2008 crisis. Even though the *nature* of finance, skill development and corporate governance rules changed as predicted, their high level of complementarity in the first two cases and mixed levels in the latter two did not. For example, in Prince Edward Island it was not only that existing institutions provided increasing returns to beneficiaries, the existing strong KOST ensured regular monitoring and changing of goals in light of new information. Quebec faced a critical juncture as the sudden scarcity of global finance caused bioscience stakeholders to search for new ways of maintaining its high commitment. This critical juncture acted as a change mechanism, coupled with a strong KOST that lead Quebec to another set of stable institutions, or, punctuated equilibrium (P. A. Hall & Soskice, 2001; Mahoney, 2000; Thelen, 1999). In both cases, the presence of a strong KOST fills the gap in the critical juncture approach. This literature does not address *how* actors react to an external shock and the decision-makers processes involved in changing the rules afterwards.

6.3 Policy Contribution and Future Research

Growing a bioscience industry is fraught with unusually high levels of complexity, uncertainty, risk and costs. By traditional measures – increased numbers of blockbuster drugs, mature and diverse biotechnology or pharmaceutical firms, patent counts, or sales revenue - most fail. But a closer examination reveals strategies and institutions that can begin to overcome these challenges as well as more realistic measures of growth in the short and medium-term. These include the quality, density and internationalization of a network, number of start-up firms growing to mid-size, and diversity of finance organizations.

The mechanism of "learning-by-learning" represented by a strong KOST explores how organizational institutions learn by self-monitoring and engaging in "reflexive" processes. These processes apply institutional memory and intelligence to regular evaluations of goals, tools and ways to identify opportunities, problems and solutions to them (Gertler et al., 2002; P. A. Hall, 1993; Sabel, 1993). But this process of organizing intelligence in social ways rather than on an individual basis can either lead to change or hold it back. It depends upon the ability of institutions to be reflexive and to monitor their success in adapting to changes in environment (Gertler et al., 2002).

It is possible for small, rural regions to design a strategy focused on niche areas of the bioscience industry such as bioactives. Balancing the niche focus with a broad range of application areas or markets can increase opportunities for growth while managing risks associated with a "one-track pony" path (S. Breznitz et al., 2010; S. M. Breznitz, 2009). But the critical factor appears to be what social learning mechanisms and policy communities are created in order to establish requisite finance, skills and corporate governance institutions.

Countries and regions attempting to transition to or at least rebalance their economies between traditional and knowledge-based industries face many challenges. In science-based industries committing to this goal requires maximizing knowledge in both the science and how to commercialize it. Neither government agencies nor industry nor the university can solve this problem alone. Policy specialists are in a stronger position to design interventions that enable rather than inhibit growth by understanding the nature, structure and logic of the bioscience industry.

A strategic approach is necessary. It involves creating a diverse, inclusive strategy team and related learning mechanisms that break silo mentalities and unleash knowledge that can be shared to help reduce uncertainty and risks while improving competencies and creating opportunities. These mechanisms must sustain through successive governments and budgets. Creating high levels of commitment to bioscience requires a knowledge-oriented strategy team led by industry regularly researching, monitoring, evaluating and negotiating commitment strategies closely with government as partners.

While scholars and practitioners alike have identified a multitude of factors related to successful cluster performance there is less understanding of what mechanisms enable high commitment strategies as well as *why* they are important in the first place. The findings will aid bioscience policy-makers and industry as they puzzle and power through the process of creating commitment strategies. They will also help economic development specialists as they address convergence gaps within their countries. This is especially important when equalizing incomes and services are goals across both “catch-up” and established provinces.

This research provides additional conclusions and testable hypothesis for future research. First, industry-led KOSTs survive successive governments. Second, sub-national jurisdictions with a history of creating learning structures straddling public and private sectors with industry taking lead are more likely to withstand a global financial shock. Third, these shocks provide an opportunity to create social learning structures. Fourth, the process of changing institutions is not always conflict-laden. Sometimes participants learn during intense negotiations leading to consensus. Social learning can unleash new ideas, ways of doing things, and change both mindsets and goals. Fifth, cooperation can occur when actors have competing and complementary interests. Firms that otherwise compete among each other may participate in a strong KOST when they have complementary interests that they cannot meet on their own. PEI and Quebec are representative cases. Finally, small regions within countries can learn to successfully grow bioscience industries while large, industrialized regions can inhibit them.

The research design is structured so that scholars can conduct future studies in emerging markets where transition from traditional to valued-added and knowledge-based industrial development is taking place. Future research can examine the complex *interaction* between networked organizations within a particular regional setting, and, their global ties especially as local governance institutions change. Research in Prince Edward Island takes this micro-level approach. Future research will involve comparing other similar provinces like Nova Scotia.

APPENDIX A

The timetables below illustrate global technological and institutional changes as well as each country’s response to them.

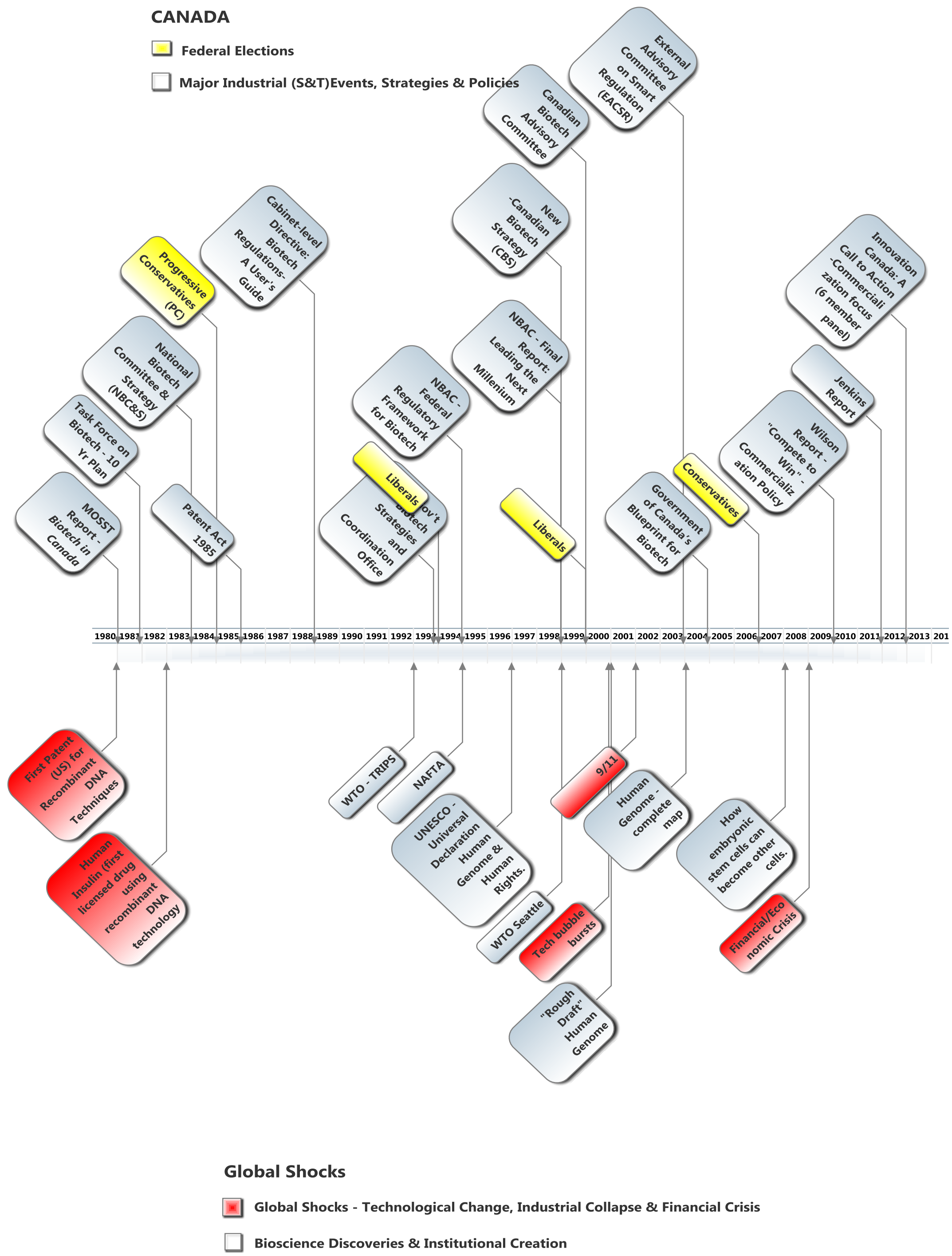

Figure 6 Canadian Technological and Institutional Changes

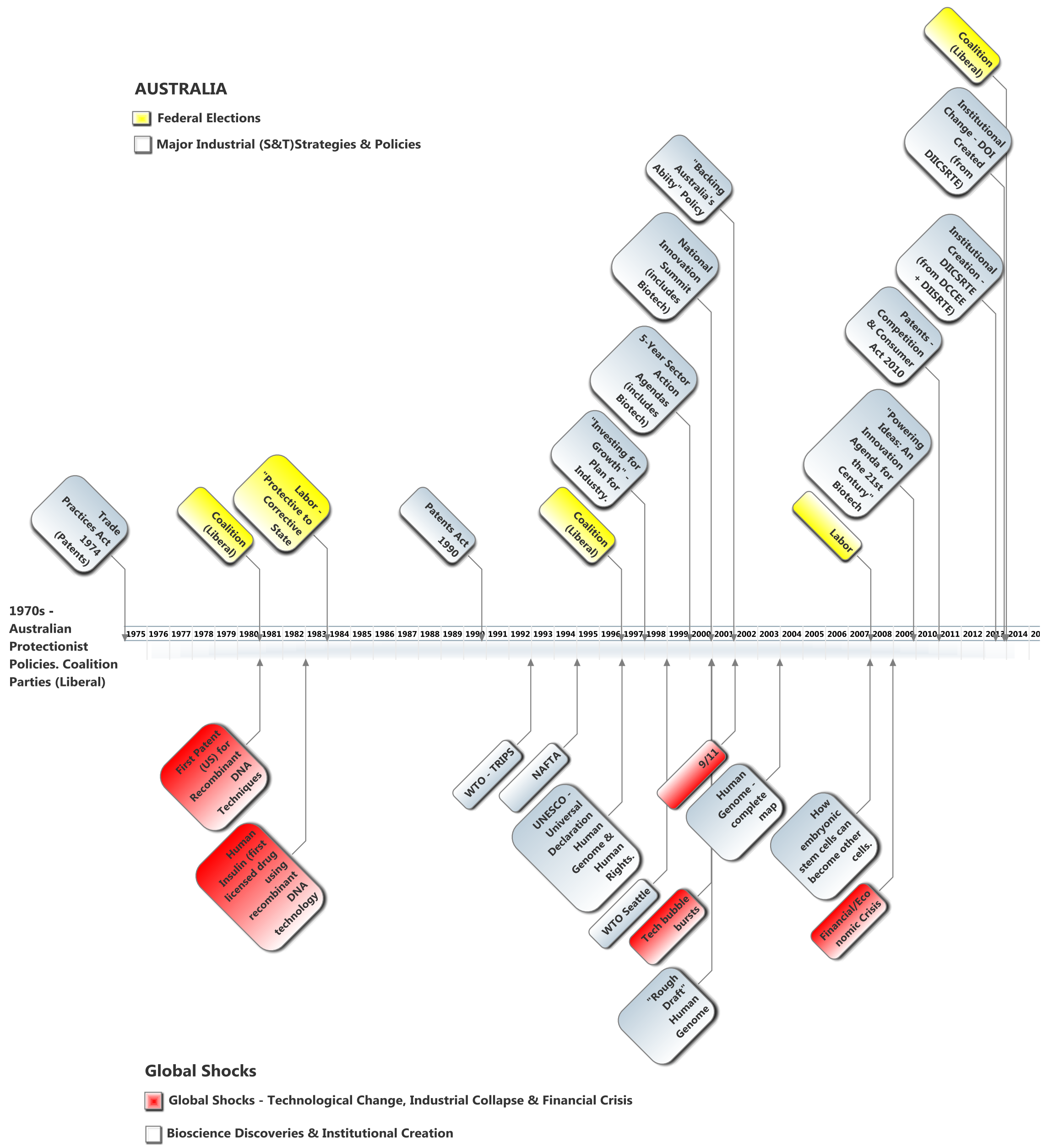

Figure 7 Australian Technological and Institutional Changes

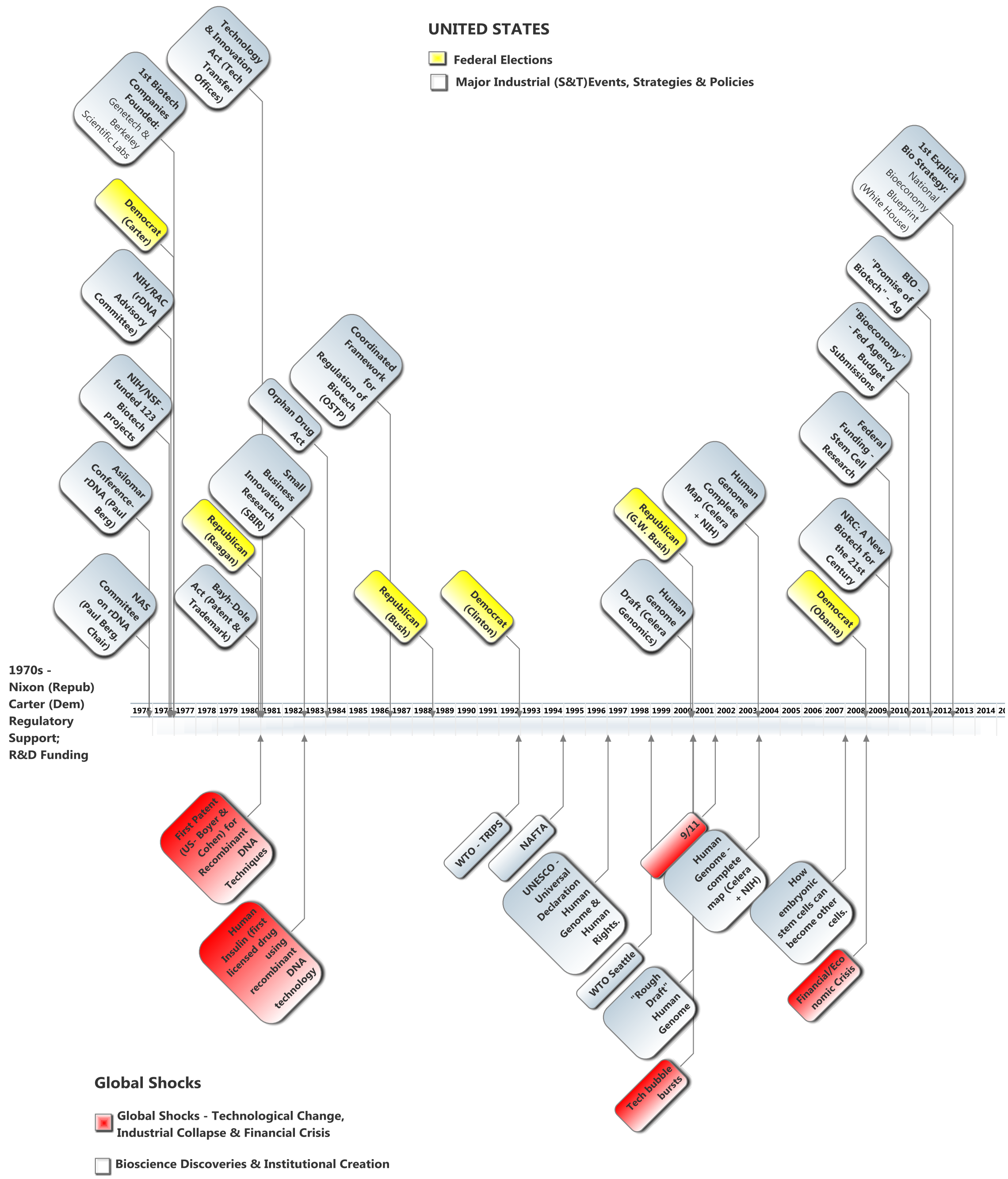

Figure 8 The United States Technological and Institutional Changes

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